TRAFFIC QUARTERLY

AN INDEPENDENT JOURNAL FOR BETTER TRAFFIC

JANUARY 1950

On Stop Signs
Results Require Facts
Street-Planning in St. Louis
Traffic Administration: Part One
Evaluating Highway Improvement
A Cooperative Experience in Dallas
Studying Road-Users' Characteristics
Priority Plan for Road Improvement
Intersection Channelization Design
Off-Street Parking in Baltimore
Prudence and Courtesy

THE ENO FOUNDATION FOR HIGHWAY TRAFFIC CONTROL

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Prudence and Courtesy

Most drivers approach their operators' test with some anxiety, even meekness. In some states, failure results for as many as forty per cent of the experienced drivers never previously examined. If fortunate in passing the test, drivers momentarily at least, accept it with a sense of pride and satisfaction. They regard it highly as something striven for, something gained. They look upon it as proof of their competence about which moments before they had grave misgivings.

With the legal requirement aside, however, drivers divide themselves generally into two classes. The emotionally unstable, irresponsible and discourteous ignore precaution after precaution. They are the *poor* drivers. They become the accident-repeaters—a major enforcement problem. Unless restrained by measures other than arrest only after a serious accident, their high accident-rate will continue. As a group, they remain a menace to safe driving.

Others drive for a generation without serious mishap. They are human too, but their behind-a-wheel emotions are tempered with a sense of responsibility, of caution, and a reasonable respect for the safety of themselves and others. They take a serious view of their privilege to drive. Their driving records are a credit to them—yet they remain *at the mercy of the dangerous driver.*

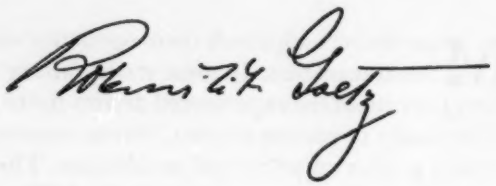
Because of varying and trying conditions under which much of our driving is done, it is essential that all drivers be competent and imbued with respect for traffic control.

Enforcement alone cannot cope with all the evils and serious consequences of the bad driving of a large part of the *public.*

Some states, as the issuing authority of the driving privilege, are recognizing the importance and effectiveness of *accurate records* with pertinent information with which to evaluate and classify drivers. Records become case histories to warn those who otherwise might continue their course of lawlessness on the highway.

These records are a cumulative, tempered form of effective en-

forcement. They force the driver to feel there is value, yes *necessity,* in keeping his record clear. In time, such records, uniformly and nationally applied, will provide safer driving and a semblance of prudence and courtesy.



Priority for Highway Improvement

ROY E. JORGENSEN

Mr. Jorgensen has been Deputy Commissioner and Chief Engineer of the Connecticut State Highway Department since July 1947. Previously he was Director of Highway Planning. From 1930 to 1942, he had been a highway engineer for the U. S. Bureau of Public Roads.

"I'm no engineer, but—"

GIVE ANY self-respecting American citizen a chance and he'll tell you what's wrong with the highway system, generally and specifically. He starts out, "I'm no engineer, but—." With that introduction he casts off all restraint and proceeds to provide the "lowdown."

He knows why a pavement is deteriorating, although the laboratory technicians are still puzzling after years of research on materials and methods of construction. He knows how to convert the chaos of the rush hour traffic on existing streets into an orderly traffic movement forthwith, although the engineers find it difficult to accomplish more than a small measure of relief with the application of every palliative. He knows, too, which roads need to be reconstructed, and is particularly insistent about the one in which he has a special interest.

This special interest "experting" has long plagued engineers. Recommendations of highway maintenance personnel, district engineers or traffic and planning technicians, albeit they represent reasonably objective professional judgment, fail to impress the citizen who has a road on his mind. The highway administrator needs something better with which to confront the pleader for a particular road. He needs something that will relate the particular road to every other part of the road system. He needs a factually established priority rating—a rating that can be used to establish the construction program and to confirm its equity.

Connecticut's First Priority Ratings

The Connecticut Highway Department's first effort to provide the priority ratings obviously necessary in the interests of making its highway planning effective was made in 1940. A trial analysis was worked up of all of the rural state highways in New Haven County, one of the eight counties in the state.

In evaluating significant factors affecting the characteristics of the state highway system and the traffic it serves, it is necessary to establish units of the highway system within which the factors to be evaluated are reasonably consistent. Recognition of this and the breaking down of the state highway system in the particular county for the priority trial resulted in the establishment of "Control Sections." These were subsequently expanded to cover the entire state and have since been the units to which maintenance costs and other data have been referred. One of the first results, therefore, of the trial priority ratings was units throughout the state highway system that have provided a basis of recording data that can be used in statewide evaluations because each of the units has a consistency of surface, type, width, age, traffic, etc.

With control sections in the county, trial ratings were established to evaluate the sections of highway on five different bases: (1) surface type; (2) surface width; (3) excessive grades; (4) excessive curves; and (5) restricted-sight distances. Formulas were developed on which the ratings for these factors could be determined from available data. It is noteworthy that only the surface type factor was established on the basis of a definite standard related to traffic volume. The remaining four factors were all determined against the mean, so that the better roads rate a factor less than one and the poorer roads rate a factor greater than one.

In our initial efforts to use the trial priority ratings established on this basis there were two primary difficulties encountered. In the first place, it was considered impractical to combine the factors established for the different features. As a result, we had five priority listings, one for each of the features considered. It was, of course, indicative of particularly undesirable conditions when the same road section developed relatively high factors on several of the ratings.

Nevertheless, it was felt that we were not obtaining the definitiveness desirable in the establishment of priorities. We did not have a specific factor that established the warrant for improvement of each road section in relation to every other road section.

The further point disclosed by the trial run in New Haven County was that on the basis of evaluations used, where sections were rated against the average, the heaviest-traveled roads became weighted so heavily that they dominated the high priority groupings. There might be considerable equity in this from the standpoint of indicating highway improvements to provide maximum benefit to road users. However, the highway system will always include roads of varying traffic importance, and a long-range plan for highway development must contemplate improvement of lesser-traveled roads as well as primary routes.

Because of the obvious shortcomings of this rating system no effort was made to apply it state-wide for priority control. However, in recognition of the importance of the control section unit for any road system evaluation, the entire state highway system was divided into control-section units. Maintenance costs have been reported by control-section since 1940. Accident reports have been coded with the control section number since 1945.

Route Studies

Another effort in the interests of coordinated and logical highway programming involved comprehensive route studies. The first was undertaken in 1945 in connection with a potential Federal-aid Secondary Highway improvement on Connecticut State Route 59. The route study was undertaken with three specific purposes in mind: first, it was intended to establish the need for improvement of the route; second, it was intended that the study would indicate the character and standard of improvement required by the traffic to be served, and third, the study was intended to provide an evaluation of methods for analyzing route and traffic characteristics so procedures might be established for general state-wide application. To summarize, it may be said that the study was undertaken to provide a correlated factual evaluation of the various factors influencing the

need for highway improvements and the kind of improvements that should be undertaken with the end view of developing a method of state-wide application.

Since making the Route 59 study, similar analyses have been made in other locations for primary highways. The range of the information considered and the character of the analysis is indicated in Figure 1, which is a composite straight-line diagram for Route U.S. 6 in the Danielson area.

The mileage along the route is shown in the straight-line diagram immediately below the traffic profile, 0 mileage being at the left and 9+ miles at the right edge of the diagram. All data are depicted in relation to this log mileage. Thus, the width of surface at any section of the route is shown directly below the traffic, operating speeds and surface type for the section. It is directly above alignment deficiencies, grades and sight distance restrictions for the particular section.

Table 1

SUMMARY OF ACCIDENT EXPERIENCE
Five Years (1940–1944)

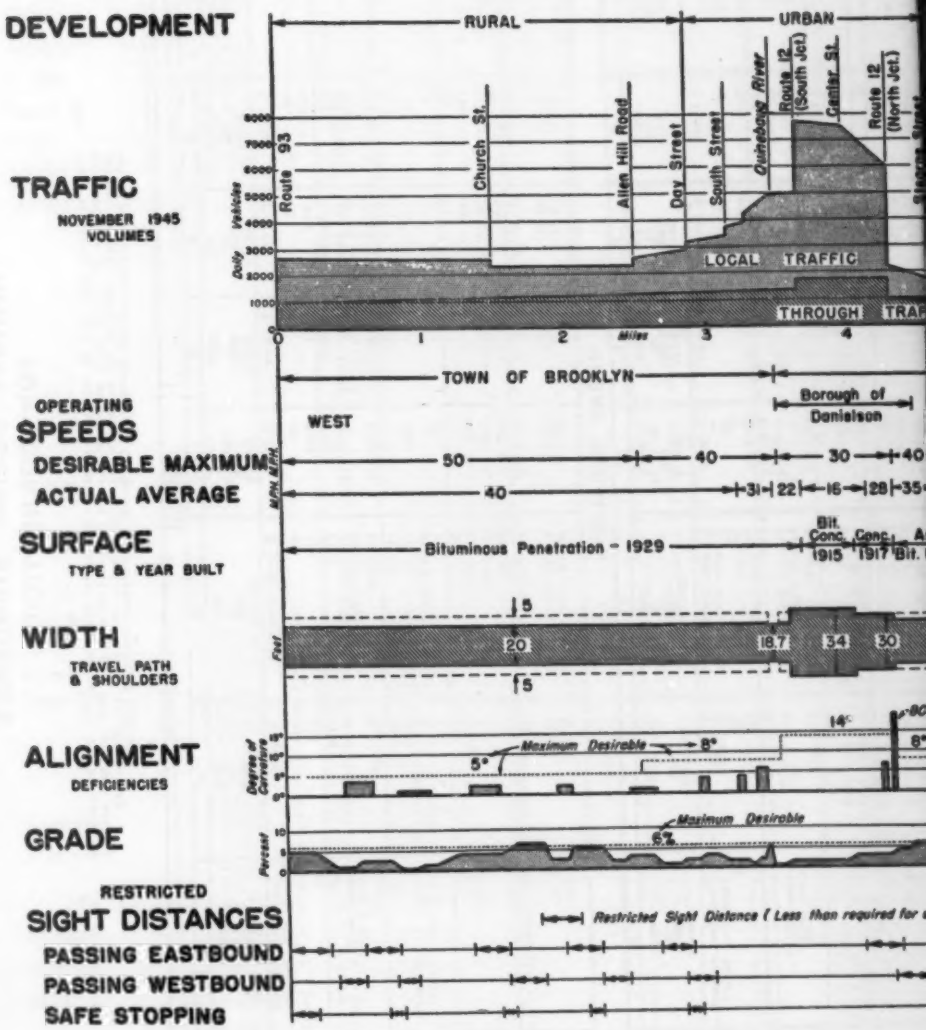
Section Terminals	*Length (Miles)*	*Accidents*	*Fatalities*	*Accidents per 100 Million Vehicle Miles*
		ROUTE U.S. 6		
Route 93				
Allen Hill Road	2.48	22	—	176
Route 12 So. Jct.	1.13	47	1	590
Route 12 No. Jct.	0.54	45	—	634
Franklin Street	2.35	26	—	366
R. I. State Line*	2.83	47	1	598
Totals	9.33	187	2	440

State Average—333 accidents per 100 million vehicle miles
*This section reconstructed in 1946

Accident records were analyzed to provide rates for the different sections of the route. Table 1 presents the results in tabular form, section by section, in the same order as the sections run from left to right in Figure 1. Table 1 shows that there were only two accident fatalities during the period covered. Statistically, these cannot be considered significant. However, it is believed the number of acci-

ROUTE U.S 6 - DANIELS

ROADWAY FEATURES AND TRA



ELSON AREA
TRAFFIC OPERATION

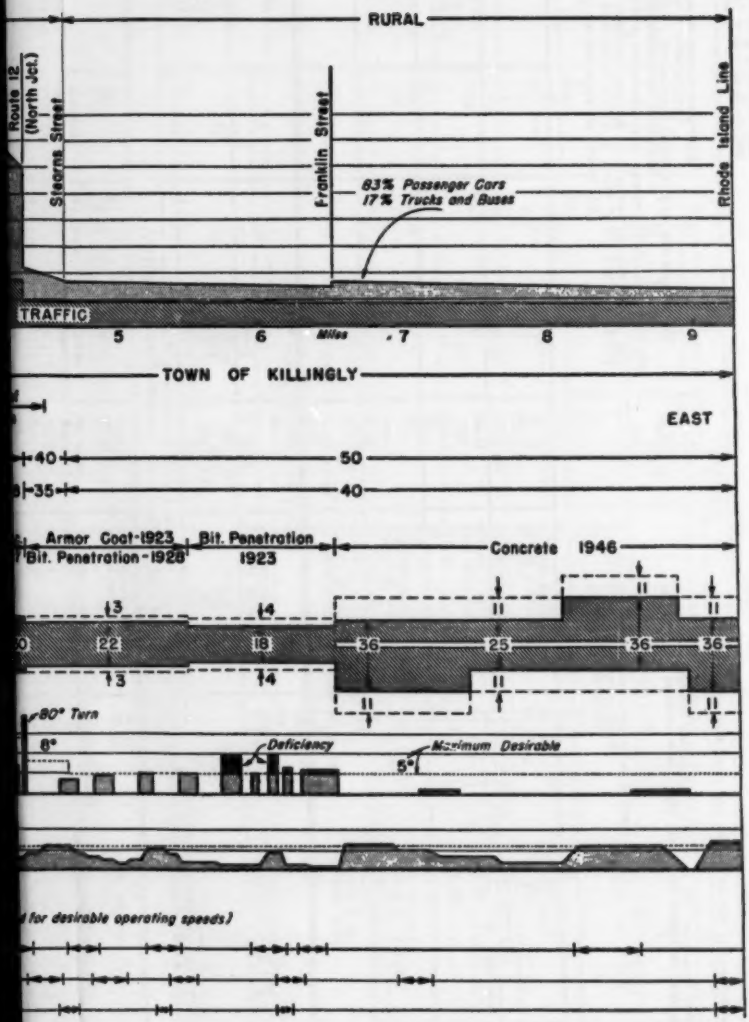


FIGURE 1

dents on each section, as distinguished from fatalities is large enough to give good rate values as shown in the last column. The minimum number for any section is 22. Because the records cover the period 1940–44, the data for the last section applies to the road before it was reconstructed in 1946. The 598 accidents per 100 million vehicle miles is a strikingly high value for this rural, relatively low traffic volume section. It indicates that good judgment was used in giving it first priority for reconstruction. The second and third sections have accident rates (590 and 634) which indicate they justify attention. Reference to the various factors presented in Figure 1 shows various inadequacies for these sections, which doubtless are contributing to the accident rate.

Table 2

MAINTENANCE COSTS
Period: Four Fiscal Years, 1941–1945

Section Terminals	*Pavement Type*	*Length (Miles)*	*Four Year Costs*				*Cost per Mile per Year*
			Pavement	*Shoulder*	*Drainage*	*Total*	
ROUTE U. S. 6							
Route 93							
Route 12 South Jct.	Bituminous Penetration	3.61	$ 2113	$4003	$1117	$ 7233	$501
Reynolds Street	Bituminous Concrete	0.35	488	234	140	862	616
Route 12 North Jct.	Concrete	0.19	102	193	54	349	459
Fall Brook	Armor Coated Bit Pen.	1.35	2108	1131	261	3500	648
Rhode Island State Line	Bituminous Penetration	3.83	6423	3523	677	10623	693
		9.33	$11234	$9084	$2249	$22567	$605

Average cost of State-wide maintenance for same period—$439 per mile per year

Maintenance costs are summarized in Table 2 in a form similar to that for accidents. The last column gives cost per mile per year, so one section can be rated against another regardless of length. Here, as in Table 1, the data for the last section applies to the road before

1946 reconstruction. The reconstructed section had the highest maintenance cost although—as can be seen from the traffic profile—it had the smallest traffic burden. The maintenance costs indicate that structurally it was not good, just as the accident rate established its functional inadequacy in the provision of safety.

The route studies gave us considerable experience in utilizing and correlating the available factual data. At the same time, our highway design standards were more positively established and provided a yardstick against which existing road standards might be evaluated. The standards are presented in Figure 2. These things, plus the example provided by the "sufficiency rating" scheme worked out by Moskowitz (see Highway Research Board Bulletin No. 17), gave renewed impetus to the development of priority ratings on a State-wide basis. This we are now doing.

Sufficiency Ratings

Moskowitz demonstrated, in the application to the Arizona state highways, that acceptable results could be obtained in a priority rating even though arbitrary assignment of weights to different factors was made. So long as the factors are significant, the assigned weights are reasonable, and consistent application is followed, the resulting ratings give a measure of adequacy that provides an equitable basis for programming improvements.

In setting up our sufficiency rating procedure we have assigned weights to different factors as follows:

Surface and shoulder width rating	25 points
Maintenance rating	12 "
Accident rating	30 "
Alignment rating	13 "
Sight distance rating	20 "
Total	100 points

However, because we are intent on using factual data only in the computation of ratings and because data on sight distances are not presently available throughout the highway system, we are limiting

our present ratings to the first four items. Thus, we are rating against a par value of 80 rather than 100. In another year we shall have the sight distance data, and will then revise our ratings against a 100 point base.

The basis for each rating is given hereafter. References to standard apply to the applicable values laid down in the "Highway Design Standards."

I. *Surface and Shoulder Width Rating (25 points)*

A. *Contrasting Surface and Shoulder Materials.* Surface width and shoulder width are separated because of the definite dividing line between pavement and shoulder and because of the reluctance of the driver to leave the surface. The total credit of 25 points is divided 15 for surface width and 10 for shoulder width.

1. *Surface Width (15).* It as assumed that a width 7½ feet less than standard is wholly inadequate and rates zero. The rating is 15 minus 2 times the deficiency. This may be expressed as follows:

$$R = 15 - 2\,(W_{ss} - W_{as})$$

Where R is the rating for surface width, W_{ss} is the standard surface width in feet.

W_{as} is the actual surface width in feet.

2. *Shoulder Width (10).* It is assumed that the effectiveness of the shoulders is directly proportional to their width, up to the standard width.

a. *For Black Top Shoulders,* the rating is 10 times the ratio of actual width to standard width. This may be expressed as follows:

$$R = 10 \times \frac{S_{aw}}{S_{sw}}$$

Where R is the rating for shoulder width

S_{aw} is the actual shoulder width
S_{sw} is the standard shoulder width

b. *For Grass Shoulders* (when the shoulder, according to standard, should be paved) the rating of 10 is reduced because of the re-

luctance to use shoulders at high speeds. The rating is 7 times the ratio of actual width to standard width. This may be expressed as follows:

$$R = 7 \times \frac{S_{aw}}{S_{sw}}$$

Where R, S_{aw} and S_{sw} are as stated above.

B. *Blending-Surface and Shoulder Materials.* Surface width and shoulder width are not separated because of the lack of a line of demarkation and because the driver feels able to use the paved shoulder freely. The total credit of 25 points is given to Roadbed Width.

It is assumed that a width 16 feet less than Standard Roadbed Width is wholly inadequate and rates zero. The figure 16 was chosen to put the value in line with the concrete roads and the non-paved shoulder roads. The rating is 25 minus 1½ times the deficiency. This may be expressed as follows:

$$R = 25 - 1\tfrac{1}{2}\,(W_{ss} + 2\,S_{sw} - W_{ar})$$

Where R is the rating

W_{ss} is the standard surface width
S_{sw} is the standard shoulder width
W_{ar} is the actual roadbed width

II. *Maintenance Rating (12 points)*

The direct roadway maintenance cost per mile for the State averages between $400 and $500. It is assumed that a maintenance cost of $1400 per mile is wholly inadequate and should rate zero, and a maintenance cost of $200 per mile is adequate and should be given full rating. The rating is 12 minus the hundreds of dollars maintenance cost per mile minus 2. This may be expressed as follows:

$$R = 12 - \left(\frac{M}{100} - 2\right)$$

Where R is the rating for maintenance cost

M is the maintenance cost per mile.

III. *Accident Rating (30 points)*

The accident rate in the State averages about 300 per 100 million vehicle miles. It is assumed that an accident rate of 1000 per 100 million vehicle miles is inadequate and should rate zero. The rating is 30 minus the accidents per 100 million vehicle miles over 33. This may be expressed as follows:

$$R = 30 - \frac{A}{33}$$

Where R is the rating for accidents

A is the accidents per 100 million vehicle miles.

IV. *Alignment Rating (13 points)*

We have adopted Moskowitz's formula* with modification to give a greater spread in the rating values. The rating is expressed:

$$R = 13\left[1 - 3\left(\frac{N - \Sigma r_c}{LD_s}\right)\right]$$

Where R is the rating

L = length of section in miles
D_s = standard maximum degree of curvature
D_a = actual degree of curvature for each substandard curve
N = number of substandard curves

$r_c = \sqrt{\frac{D_s}{D_a}}$ proportion of standard (intensity) for each curve.

Table 3 shows the sufficiency ratings developed for the sections of Route U. S. 6 in accordance with the procedures described. The last section replaced 7006–02 at the completion of the 1946 construction. Comparison of the ratings indicates improvement in sufficiency in all items. Although the accident rating is only half of perfection, this poor rating is based on one year's record of only eight accidents —too few to provide a reliable accident rating.

The development of sufficiency ratings presumably places all state highway road sections in priority for improvement from least sufficient on up to the new construction which meets current stand-

* See p. 39 of Highway Research Board Bulletin No. 17.

ards. It might be assumed that the answer to all our problems of programming is thereby provided. There are considerations, however that will not permit going right along project by project with the sufficiency ratings.

Table 3

SUFFICIENCY RATINGS

Control			Rating				
Number	*Section*	*Length (Miles)*	*Surface Width*	*Maintenance*	*Accidents*	*Alignment*	*Total*
			ROUTE U. S. 6				
7003	02	4.06	10	8	6	11	35
7013	01	0.35	10	5	0	13	28
7013	02	0.19	10	9	7	11	37
7006	03	1.35	10	8	12	13	43
7006	04	0.79	10	7	8	6	31
7006	02	3.04	13	8	12	10	43
		7006–02 was replaced in 1946 by 7006–06					
7006	06	2.66	24	10	15	13	62
Perfect rating would be			25	12	30	13	80

Programming of one project frequently affects adjacent sections if a long-lived adequate facility is to be provided. In other words, proper correction of the insufficiency of one section must be coordinated with the overall development of the remainder of the route and connecting routes. This is one of the important things we have learned from our route studies.

In some cases it may be found that the required improvement is so expensive as to make immediate construction impractical. In other cases, it may be necessary to defer immediate action in the interests of spreading the program geographically. Availability of plans and personnel are additional considerations that might alter the priority listing.

The foregoing is in no way intended to imply that these are reasons for ignoring the priority determination. It is intended only to show that there must be a tempering of the listing as annual programs are prepared. And, regardless of this tempering, there are two things the priority listing positively will do:

First, it will keep in front of the highway administrators a con-

tinuing emphasis on the worst sections of the highway system. If it is necessary to pass over certain sections in the programming, the administrators will feel obligated to have good reasons for doing so. Furthermore, as each program is prepared, consideration must again be given from top priority down.

The second important service of the priority list is in forestalling pressures which are always at work in the interest of someone's special project. There is provided in the priority list a factual record to assure that these special projects are weighed against the remainder of the highway needs. The priority list makes the highway administrator's job easier and guarantees to all of the road users that the program is formulated to meet road needs and not to satisfy political pressures.

Development of Off-Street Parking Facilities in Baltimore

W. G. EWALD

Mr. Ewald is chairman of Baltimore's Off-street Parking Committee and executive vice-president of that city's Retail Merchant Association. In 1926 he joined the staff of the Baltimore Association of Commerce and in 1931 was elected Secretary. He has played a prominent part in community-wide efforts to solve traffic and parking problems in Baltimore. He helped form the Community Council on Street Traffic and has served as its Coordinator since 1946.

BALTIMORE has no parking authority. On the contrary, Baltimore has elected to solve its parking problem by a commission form of municipal agency, with definite statutory limitations imposed upon its operations.

The underlying philosophy of the Baltimore plan is to deal comprehensively with the parking problem within the spirit and framework of our traditional competitive enterprise system and without subsidy or special privileges through tax abatement or other concession. Although the Commission has been in existence a relatively short time, we have confirmed our original belief that this is a tough assignment. It challenges our greatest ingenuity and initiative and at the same time taxes our stamina and perseverance.

In the process of creating and establishing a working commission, we have encountered a great variety of difficult and complex problems, and consequently our progress has been slower than we had hoped or expected.

Step One

The initial step in developing the Baltimore program was taken by the Municipal Commission on City Plan in 1945 through the appointment of a Sub-Committee on Traffic and Parking to study the off-street parking problem and submit recommendations. After an extensive study, this sub-committee reported that the parking prob-

lem offered the three following alternatives: First, the creation by the state legislature of a parking authority to deal comprehensively and on a planned basis in assisting private enterprise—one that could collect sites and provide tax relief on improvements over a period of years; or second, municipal financing, construction and operation of needed facilities; or third, to let nature take its course and do nothing.

With a deficiency of 5,000 off-street parking spaces in the central business district, the sub-committee concluded that the time had arrived for the community to face the facts and adopt an action plan that would increase the parking supply rapidly. It therefore recommended the creation of a parking authority with the power of condemnation and adequate loan funds to be made available to private operators at rates sufficient to meet full interest and amortization charges. These recommendations in substance, but with some modifications, were approved and the City Government sponsored the introduction of suitable legislation into the 1947 session of the Maryland Legislature.

This legislation was vigorously opposed and after protracted debates and delays it was finally enacted, but in an amended form. While the final product did not fully conform to the originally proposed legislation, at least it offered a promising beginning in solving the parking problem. In due time, appropriate conforming legislation was introduced into the City Council to create an Off-Street Parking Commission with powers necessary for its effective operation.

The legislation met strong opposition. The chief difficulty was the Council's reluctance to delegate to the new commission its traditional control over the locations of sites for establishing parking facilities. The controversial issues were resolved in due time, but only after a second ordinance was presented to the Mayor for his signature, the first one having been rejected because of the extreme restrictions and limitations imposed upon the commission's operations.

With the enabling legislation and the conforming municipal ordinances finally enacted, the Mayor in February, 1948 appointed a five-man unpaid Off-Street Parking Commission consisting of two

attorneys, one banker, an insurance executive and a commercial organization executive.

Checking With Other Cities

The newly created commission had the benefit of a comprehensive parking survey made in 1946 under the joint auspices of the federal, state and city governments. This survey showed a deficiency of 5,048 spaces in the downtown area of Baltimore, and it should be noted that this figure coincided closely with the previous survey made by the Planning Commission in 1945.

With this data, with the power of condemnation and a million dollar loan, the commission endeavored to find out at once how other cities were attacking the problem and to benefit from their experience.

It soon discovered that virtually all of the large cities and some of the smaller ones were in the same position as Baltimore. It learned that while many cities were *planning* solutions, few had advanced far in actually constructing the needed facilities. There seemed to be a lot of talk but very little concrete action. Our commission found that few cities had even established official commissions. Among those that had done so, the Motor Vehicle Parking Agency in the District of Columbia seemed to exemplify the type of operation envisioned in Baltimore, and consequently the Baltimore Commission leaned heavily upon the Washington agency in laying the foundation for its operations and in starting its program.

Aware of the public mandate for prompt action, the commission applied itself assiduously to formulating an aggressive attack based upon proved measures. It proceeded to carry out these measures in accordance with a comprehensive plan coordinated with the community's over-all program for dealing with the street traffic program generally.

Since the commission, in accomplishing its purposes, was expected to depend largely upon the efforts of private enterprise, it was deemed highly important at the very beginning to establish a clear understanding of its intentions and its working relationships with those engaged in the parking business. As its first step therefore

it issued a general policy statement, in which the Mayor and City Council concurred, outlining its plans and procedures.

The Statement in Part

This statement declared the commission believed that off-street parking facilities on a permanent basis and in accordance with a long-range plan, were essential to the preservation, stability and efficient functioning of all business districts; that while it recognized that some municipalities were actually operating parking facilities, the commission did not consider such municipal operation desirable for Baltimore except as a last resort and only after all other alternatives had been exhausted. It further stated that by prudent use of its powers and public funds in the acquisition of properly located sites, the commission would stimulate, correlate and supplement the efforts of private enterprise.

Obviously the purpose of this declaration was to allay any fears that the city government intended to go into the parking business in competition with private enterprise. It was also intended to encourage private enterprise to proceed with its own projects and demonstrate its ability to solve the community's parking problem.

Having thus proclaimed its policy, the commission then called for less talk and more action on the part of all concerned. Exemplifying its own mandate for quick action, the commission itself promptly initiated a study of the possibilities of utilizing city-owned property in the water-front area. Within two weeks it announced the selection of a site in that area involving the creation of 250 additional spaces on a one-level parking lot capable of being expanded ultimately to accommodate 800 cars.

The commission next turned its attention to privately-owned and operated facilities, with a view of expanding well-located, one-level lots into multiple deck facilities. Here the commission got its first shock. It found that the statutory limitations imposed upon the use of loan funds were of such a nature as virtually to hog-tie its operations.

The chief obstacle arose from the fact that no proceeds from the loan could be expended (a) until the commission had prepared a

written recommendation setting forth the terms and conditions upon which any property could be sold or leased, and (b) until the Mayor and City Council, with the approval of the Board of Estimates, had entered into a binding contract with an operator for the sale or lease of any property at a price, charge or rental sufficient in amount fully to reimburse the city for all expenditures to be made in connection therewith and all interest on the funds borrowed and so expended on the project, and for all estimated real estate taxes that would be lost as a result of the acquisition of such property.

Difficulties

The commission soon found that operators were unwilling to enter into such an agreement without knowing in advance the amount of money they were expected to pay and the type of facility they were expected to operate, all of which was impossible to ascertain until the land was actually acquired, working plans prepared and contractors' estimates obtained. The commission was also prohibited from using any loan funds for the retention of architects or engineers to prepare preliminary plans.

Faced with this impasse, it publicly acknowledged its inability to function efficiently and recommended that early steps be taken to remedy the situation. Many conferences ensued with the Mayor, the City Law Department, private operators and general business leaders of the community, after which agreement was reached that new legislation should be prepared and introduced into the special session of the state legislature in June of 1948, only a few months after the commission had started its operations.

This new legislation, which was intended to eliminate all of the known obstacles, was promptly enacted. The legislature also reauthorized the submission of a $5,000,000 loan for off-street parking, because in the process of securing new enabling legislation, it was necessary to repeal the earlier statutes and with them the authority to issue loans. The new $5,000,000 loan was overwhelmingly approved by the electorate in the last general election.

The new enabling laws empower the commission to exercise its initiative in acquiring sites and in the preparation of project plans without first having to enter into a binding contract with a private

operator. The law also empowers the commission to commingle its funds with those of private operators on privately owned projects without taking possession or otherwise controlling the project. This is believed to be a unique grant of authority and is intended to serve a twofold purpose. First, an operator whose personal funds are invested in business is expected to produce a more satisfactory operation than one without a personal investment; second, the commission's authorized funds can be expanded to increase their effectiveness by commingling them with the operator's own funds.

Thus armed with broader statutory powers, the commission then entered upon its second legislative phase of operations, which started on January 1st of this year. While awaiting approval of the resubmitted off-street parking loan by the voters, the commission used the period from July to November of 1948 to discuss with all of the private operators an over-all plan for new and expanded projects, so that these projects could be made ready for prompt execution as soon as the anticipated loan funds should become available.

A Plan for 6,000 More Spaces

During this preparatory period the Acting-Director interviewed all of the principal operators, and after studying their various proposals prepared a comprehensive plan providing for approximately 6,000 additional spaces, 4,000 of which were to be located in the central business district and 2,000 in its perimeter area.

With this data assembled, the commission was ready to proceed with its program. In order to preserve confidential relations with private operators, it conferred separately with each one and outlined the commission's general policies and procedure. It offered to make loans to responsible operators of parking facilities, as well as those contemplating entering this business, to expand existing well-located lots into multiple deck structures or to acquire new sites, these loans to extend over a 20-year period at 2½% interest. The operator has the privilege of redeeming the loan any time before the 20-year period without paying any interest beyond the date when the full amount of the loan is paid.

The assessment on the property involved is constant throughout the loan period, and the assessment basis is that which exists at the

time the project is started; the tax rate, however, varies each year to conform with the tax rate as established by the Board of Estimates. The operator is required to pay monthly amortization, interest and taxes.

The commission also outlined the steps to be followed by prospective operators in its preliminary consideration of a project. Briefly, this procedure calls for the submission of: (a) a sketch showing the outline of the property or properties involved, as well as names of owners; (b) a sketch of the structure showing the proposed lay-out; (c) estimated cost; (d) the amount of funds the operator proposes to contribute to the total cost of the project; and (e) the present and proposed capacity in car spaces.

After this preliminary information has been checked by the commission and approved by the Planning Commission, the Police Traffic Department and the Fire Department from the standpoint of planning, traffic flow and economic feasibility, operators are then requested to submit a formal application to the commission.

The application treats in detail the economic feasibility of the project; a profit and loss statement for the previous year's operations if the operator has been engaged in the parking business; a financial statement of the applicant; a profit and loss statement covering his existing facilities, with an estimated statement covering his contemplated facilities; and an outline of the proposed method of operation and rates to be charged.

In carrying on its current program, the commission has found it desirable to give priority to those facilities which are or will be located in the areas of greatest need, as determined by the official parking survey. It has also adopted the policy of diversifying its loans in order to encourage the widest possible participation by private operators in the commission's program as well as to insure maximum safety of its investments.

Construction Is Started

From the above review, it is apparent that the commission is still in its early stages of operation. Consequently it would be premature to make any broad claims concerning its actual or anticipated ac-

complishments. At the present time two formal contracts have been approved by the Off-Street Parking Commission and the Board of Estimates and two more contracts are in process of consummation.

On July 25th, 1949 actual construction was started on one of the aforementioned projects. The commission is cutting its proverbial eye teeth on the first proposals and has been obliged to deal with a number of major policy matters in connection with it. These contracts, when approved, are expected to establish a pattern for the commission's future operations and the commission in the future will be able to proceed much more rapidly. (The commission already has been obliged to ask for sixteen official legal opinions from the City's Law Department.)

One of the significant by-products of the Baltimore plan is the fact that, as a result of the favorable climate created for private enterprise through the commission's initial reassuring policy, the parking industry itself is going ahead with projects not requiring commission aid. At least three such projects are currently providing 700 additional spaces at strategically located sites in the central business district.

Taking all things into consideration and recognizing the complexity of the problem we are dealing with, the Baltimore plan appears at this time to give some promise of substantially alleviating the community's parking problem. It may not furnish a complete solution, but at least we have made a positive start and we believe we are now on our way.

Street Plan and Interstate Highway Experience in St. Louis

HARLAND BARTHOLOMEW

Mr. Bartholomew has been an engineer on the City Plan Commission of St. Louis, Mo. since 1916. Since 1926 he has also been a consultant on the National Capital Park and Planning Commission of Washington, D. C. In 1941 he was appointed by President Roosevelt as Consulting Highway Specialist on the Inter-Regional Highway Committee. He was a member of the Missouri City Planning Board in 1942 and 1943. From 1939 to 1941 he was Chairman of the Executive Committee of the City Planning Division of the American Society of Civil Engineers. From 1933 to 1938 he was Planning Director of the St. Louis Regional Planning Commission. Mr. Bartholomew is author of "Urban Land Uses" published by the Harvard University Press in 1932, and of numerous papers, pamphlets and articles in technical magazines. He is former President of the American City Planning Institute and of the National Conference on City Planning. He is a former member of the Organization Committee and Chairman of the Committee on Sub-Division Layout of the President's Conference on Home Building and Home Ownership in 1931. Mr. Bartholomew has been engaged in planning work for the last thirty-two years.

WHEN motor cars began to appear on city streets after 1910, banter and derision soon gave way to a realization that "automobiling," first regarded as a sport, was here to stay—as a means of transportation.

By 1916 in St. Louis some 16,000 vehicles were registered, and the City Plan Commission estimated there might be 200,000 by 1940. Today there are 186,000 registrations in the City of St. Louis alone and an estimated total of 346,000 in the St. Louis Metropolitan District.

More than 94,000 automobiles now enter the St. Louis central business district daily, exclusive of a large number of street cars, buses and other vehicles.

In St. Louis, as in other cities, the early street system was a haphaz-

ard arrangement of narrow streets, mostly 60 feet wide and with 36-foot roadways only indifferently improved and paved. There was no preconceived plan, no semblance of orderly arrangement. The accommodation of many thousands of vehicles, horse-drawn or self-propelled, had never been considered. Obviously the streets could not accommodate an unusually large number of vehicles. The new traffic created an urgent need for plans to handle ever-increasing volumes. The City Plan Commission appointed in 1915 immediately undertook to prepare a "Major Street Plan" as a most important part of the newly adopted Comprehensive City Plan program.

Design and Financing Early Major Street Plan

In St. Louis the Major Street Plan comprised about 25 per cent of the total mileage of city streets. The plan consisted of a series of main thoroughfares radiating from the central business district as spokes from the hub of a wheel, supplemented by "cross-town" thoroughfares from one-quarter to one-half mile apart to accommodate both east-west and north-south traffic movement. As far as possible existing streets were used. These main routes were designated as either 100-foot (8-lane) or 80-foot (6-lane) "major streets." By systematic widening, extending and connecting of these several routes, main traffic movements could be channelized sufficiently to meet foreseeable future demands.

In 1923 St. Louis voters approved an $87,000,000 capital improvement program which included $8,650,000 for "establishing, opening and widening streets," and $5,800,000 for "paving and improving streets." Nearly all of the more important projects in the Major Street Plan have since been carried out.

The total cost of the program is estimated at approximately $40,000,000, the difference between this sum and the $14,450,000 in the 1923 bond issue having been paid for by special assessment on private property, usually including both the frontage on the new thoroughfares as well as in tributary areas of benefit. It should be noted that this entire program was paid for by St. Louis taxpayers despite the fact that many millions of dollars were paid simultaneously to the state by St. Louis motorists in gasoline taxes and license

fees. The latter funds were used in the development of a system of state highways with no expenditures in or refunds to St. Louis.

As a result of this long-range planning and coordinated capital expenditure, one can move today quite freely between one part of St. Louis and any other part on a wide, well-paved, well-lighted major street. Even rush hour traffic loads are not as prolonged or as acute as those experienced in many other cities. A highly significant fact is that more people are now entering the central business district than ever before. Furthermore, the last estimates of total retail sales in the downtown business district showed that these were approximately the same percentage of total retail sales in the whole metropolitan area as they were in 1925—an experience which apparently has not been paralleled in other large metropolitan areas.

Traffic Continues to Grow

The total volume of traffic on St. Louis streets continues to grow. In the interests of safety and control, traffic signals have been installed at numerous major street intersections. In the central business district all parking has been prohibited for several years during morning and evening rush hours, and more recently all parking has been prohibited from 8:00 a.m. to 6:00 p.m. on the business district extensions of the more important major streets. The City Plan Commission, the Board of Public Service, and the Public Service Company, which operates street car lines and buses, recently collaborated in reroutings to reduce traffic congestion and expedite both public transit and private vehicular movement.

A New Major Street Plan

Within twenty-five years it is altogether possible that total traffic flow on certain routes in peak periods cannot be accommodated by strictly surface major streets. The City Plan Commission recently revised, published and adopted a new Comprehensive City Plan of St. Louis. The commission has endeavored to look ahead another twenty-five or thirty years and devise a plan which will best accommodate increased traffic. In the new Major Street Plan the total

mileage has been reduced slightly and three new classifications of thoroughfares have been added to the original system of 6-lane and 8-lane major streets. The new classifications include interstate highways (8 or 10 lanes), expressways (6 or 8 lanes), and secondary streets (4 lanes). The plan also proposes grade separations at six of the more important major street intersections.

A second capital improvement program of $63,000,000 was recently approved by the electorate of St. Louis. One item of $8,600,000 for "street opening and widening" will provide for several more 6- and 8-lane major streets in addition to the city's share of the cost of the first program of interstate highway construction, i.e., the north and south approaches to the eastern edge of the central business district.

The Interstate Highways

The new State Constitution of Missouri now makes it possible for St. Louis to participate for the first time in the expenditure of state highway funds. Since five state and federal highways reach St. Louis (U.S. 50 E.—U.S. 40 E. & W.—U.S. 66 N.E. & S.W.), it is proposed to construct interstate express highways through the city to accommodate the more important main traffic flows without disrupting the residential and industrial areas. This can be done mainly by two arterial routes: one directly east and west through the central part of the city on the south side of the industrial area along the railroads in the Mill Creek Valley; a second, north-south route generally paralleling but several blocks removed from the Mississippi River. Of two strategically located north-south cross-town routes, one is a by-pass slightly west of the business district and the other will be a distributor route passing through midway between the business district and the city limits.

The interstate highway routes constitute 21.78 miles out of a total of 303.54 miles in the city's Major Street Plan. First construction, for which detailed plans are now being drawn, is a leg one and one-half miles long leading southwest from the central business district. The next will be a similar leg leading to the northwest. These will further reduce traffic concentration in the approaches to the business district. This represents an approximate 6-year program

of construction, costing approximately $6,000,000 per mile. The entire interstate highway program, arterials and cross-town, will take approximately 43 years to complete unless costs are substantially reduced (which is not probable) or federal and state fund allocations are increased, or both.

Factors in Highway Location

The City of St. Louis is elliptical in shape with the central business district near the outer river boundary. Practically all desire lines in any origin and destination traffic survey would be found west of the business district. However, to place an interstate highway along the west boundary of the business district would add congestion where too much already exists. Ultimately, it would also cause a shift of property values westward.

The city plan has long shown express highways leading northwest and southwest from the *east* edge of the central business district. This will have several benefits. First, it will stabilize values in the business district. Next, it will relieve congestion now too much concentrated on the west. Last, and most important, it will open up an entirely new facility for both vehicular and bus traffic and greatly augment present mass transportation facilities free from conflict with present facilities. It will help to balance the total traffic flow into and out of the business district. These are substantial advantages. They are benefits to be derived from good planning and are not based strictly on existing traffic flow.

The location of the expressway in St. Louis was chosen, in addition to the reasons given above, because it offered an opportunity to construct a large automobile parking facility on the riverfront where access would be unhampered by conflict with other traffic flows.

The Expressways

Approximately 50 per cent of all traffic from the central business district is westbound, thus placing a very heavy burden on the east-west streets. These thoroughfares will be the first to experience an excessive traffic load, although two new 8-lane and three new 6-lane

major streets have been opened in recent years. The new Major Street Plan proposes to build a new expressway directly to the west in conjunction with a large slum clearance plan. The new route will extend for a distance of two miles to Grand Boulevard, then use an extremely wide existing thoroughfare, Forest Park Boulevard, for two miles to Kingshighway; then parallel the Wabash Railroad to a connection with Skinker Boulevard practically at the city limits. This will probably be the most heavily used traffic route and since it is not a part of the interstate highway system a major portion of its cost will probably have to be met locally.

The Secondary Streets

Traffic originates in all parts of the city's area. It cannot always flow directly into the main arterial or trunk line thoroughfares. Frequently it will use a secondary type of street for considerable distances. Experience has shown that many of these secondary streets need not have unusually great width. A 4-lane width will be sufficient in many instances. Street widening is expensive and can be avoided on these streets, especially if parking is prohibited during periods of heavy traffic flow.

Lessons from St. Louis Experience

By providing a *system* of fairly satisfactory traffic thoroughfares serving all parts of the metropolitan area, it has been possible to create traffic flow in this large city without extreme congestion and at relatively moderate cost. A strictly surface system has the disadvantage of lower speed for traffic than is possible on separated grade highways. In attempting to solve the large scale problem of total traffic flow in cities, however, cost becomes an important factor. If unlimited funds were available a substantial mileage of separated grade express highways would unquestionably be desirable. But at a cost of $5,000,000 or $6,000,000 per mile it will not be possible for St. Louis or many other cities to undertake a large program of separated grade express highways. Most of the street widenings in the central built up areas of St. Louis have cost an average of about $1,000,000 per

mile. In this city it has been possible to at least keep pace with the growing traffic problem through the street widening program. It is believed that future needs can be met by combining a limited amount of additional street widening with separated grade construction of interstate highways and one or two expressways strategically placed.

One disadvantage of the separated grade express highway will be the disposition of traffic at its central business terminus—or at the central business district where the route continues rather than ends. Experience in St. Louis has indicated that a well-designed major street system has helped to prevent congestion by encouraging a fairly uniform distribution over several streets.

Size and Character of City

Each city presents a different set of conditions. It is impossible to establish universal standards. Small cities can afford little or no separated grade highway construction, whereas the larger metropolitan areas with their unusually heavy volume of traffic flow will require extensive separated grade expressways. In solving city traffic problems we should use all the devices at our disposal. Carefully studied traffic control, restricted curb parking, improved transit service, extensive off-street parking facilities, are essential. A Major Street Plan which is an integral part of a Comprehensive City Plan coordinating all these measures is a fundamental starting-point.

The Dallas Cooperative Experience in Achieving Traffic Results

CARL J. RUTLAND

Mr. Rutland, Chairman of the Citizens' Traffic Commission of Dallas, is an official of the Texas Power & Light Company in charge of claims, insurance, safety and training. The Commission has achieved outstanding results. Working as a team with public officials, the Commission has secured material reduction in death and injury rates, and in motor vehicle insurance premiums for Dallas County. Because of his civic leadership in this work, Mr. Rutland was selected as Dallas' most outstanding citizen. He is Vice Chairman of the Highway Committee of the Chamber of Commerce; founder of the Texas Safety Association. He has been Chairman of both the Traffic and Public Utilities Sections of the National Safety Council.

MANY city councils or other policy-making bodies of local governments have not fully accepted their responsibilities in the control of traffic, the Number One of four major problems of any large community.

Traffic is regarded in this article as street planning, traffic engineering, enforcement by police and courts, and a continuous information program for public benefit on traffic plans, driving practices, and progress. *Information program* means making correct driving popular and advertising the value and reasoning of the city's traffic policies.

Fewer than a handful of municipalities make only a token appropriation to set up even a small department to sell this product. The responsibility sooner or later must be accepted in full by our city councils. They are elected to establish community policies. Traffic is definitely a major community problem. It requires leadership to establish policies and, since practically all control factors are official, top-ranking city officials must assume this job.

If they don't do it, who can, or who will? They have recognized and accepted their responsibilities in the other three menaces to human life and property—fire, crime and disease. Of each dollar

appropriated for controlling these menaces, approximately forty-nine cents goes for public health, good water, sewage disposal, city hospitals, food inspection, etc.; twenty-four cents goes for fire control —pumping plants, reservoirs, standard requirements for mains, fire fighting equipment and stations, firemen, arson laws; seventeen cents, for crime control—laboratories, fingerprinting, detective personnel. About a dime goes for traffic—out of proportion and inadequate for the problem.

Motor vehicles increase in numbers year after year. The end is nowhere in sight. More and more they become complex factors in social and business life. Few cities have developed a major, comprehensive, long-range traffic improvement plan, particularly with regard to mass transportation, off-street parking, street widenings and extensions, and better use of existing street facilities, and continuously, progressively, year after year, work toward its accomplishment.

Too Little Coordination

Indisputably traffic affects every individual, every type business, every day of every year. Obviously, the common objectives of those affected are economics, transportation, public safety, and the efficient movement of vehicular traffic. While recognizing this common interest, we see too little coordination of effort to achieve the desired results.

Few cities have formed a united group representing all these interests—the merchant, the mass transit executive, the school head, the public official, parking interests, the Bar Association, the realtor, the motor freight hauler, the Chamber of Commerce, the manufacturer, the insurance man, the civic leader, the PTA and a few other similar influential groups, persons, or organizations putting their feet under the table and continuously conducting research, planning and activating the program. Either lack of knowledge, or the courage to tackle this problem as it should be tackled, is somewhat of an indictment of community leadership, particularly official leadership. The resulting economy and humane benefits certainly justify the existence of some sort of effective community traffic organization.

In many instances we see within the municipal administration itself the same lack of coordinated effort. The public works director, the traffic engineer, the judge, the utilities supervisor, the city planner, the police chief and the city attorney—all have varying responsibilities for traffic improvement—are not brought together at regularly scheduled meetings presided over by the city manager or comparable executive officer, to study plans, adopt and activate some and submit others for public approval.

In general, each department head works on his own or at a tangent. There is no real directing, coordinating leader. Every major traffic project involves most of these positions. If there isn't some inspired feeling of creative responsibility in each department, and a pooling of their thoughts and efforts from conception and planning to completion, a worthwhile traffic project is never developed, or if one is, it stands a good chance of failure.

Most city governing bodies are doing a much better job in water, sewer, public health, crime and fire, than in traffic. Traffic is the newest of these problems. On the other hand, it involves dealings with more citizens than any of these others, and because of continuing controversies over traffic matters, the public official takes the line of least resistance and the needed improvements are not carried out. Traffic becomes everybody's job with more talk and less action.

Commission or Group Action Needed

Surely the problem is of sufficient importance to justify some sort of commission or action group to get more things done, until perhaps sometime in the future the municipal officials will have assumed full leadership in all fields of traffic flow and safety, and public attitude will have turned to support their efforts.

This may be an independent community group of civic leaders and public officials, or it may be a type of commission serving as an official arm of the city government with the same type of representatives on it as in an independent group. It should attain high standing in the community; first, because of the high character of the persons represented in the organization and, second, because of the obvious soundness of the projects which will be submitted.

It must be respected and non-political except as it supports public officials who do good jobs and frowns on those who do not. It will recruit public opinion favorable to constructive measures which the official agencies elect to carry out. It will always give these agencies the proper public credit for the official job done, reserving little public credit to itself. It will advertise and take the lead in selling the project to the citizenry which, in many instances is more easily done by it than by the officials.

The set-up and the program of the Citizens' Traffic Commission of Dallas, after several years' effort of lifting itself to a high level in the community, is very definitely proving the soundness of such a community coordinated group. It had no chart or pattern to follow when it was organized ten years ago. It knew little of the official side of the entire problem. The official had never had public understanding when it became necessary to refuse to carry out some questionable demand. The citizen always thought he had every answer to the traffic problem and frequently took the position of telling the official how to run his business. The official, too, in the absence of public support for improved enforcement or a change in an existing traffic movement, did nothing or did only that which he thought was politically expedient. The group stood together, official and unofficial interests learning and understanding each other's problems.

Mutual confidence developed. Teamwork prevailed. Problems were presented for study. Today there is not the confusion of issues, either within the personnel of the commission or by the citizenry as the commission more and more, through the press and radio, analyzes the problems and makes recommendations. Little opposition is met in carrying out a project. It becomes the job of the representative from each organization to sell that project and thoroughly inform his membership on the value of it.

Of course some mistakes have been made in strategy and timing, but practically all of the plans submitted have been carried out. Others are temporarily on the shelf because the commission understands that there are financial limitations, inadequate state laws, or the time is not right to carry them out.

In the case of nearly every recommendation to the governing body, the individuals of that body, or city departments concerned,

have been a party to approval of the recommendation beforehand. In many instances the public official dumps into the lap of the commission a particularly worthwhile project for study and sale.

Commission No Pressure Group

In the beginning, the commission adopted one very definite policy—that it would not be a pressure group. It decided to follow purely democratic principles; that it had a good product to sell, and that if such product couldn't be sold to the citizenry or the public officials, the fault was not with the product or the buyer, but with the seller.

It also recognized that it couldn't in any degree assume any of the responsibilities of duly constituted authorities. It believed teamwork was needed and that the traffic problem, particularly the death and injury toll, might be regarded as an annual catastrophe. If these individual tragedies were squeezed into one incident, at one location, and at one time of the year, it truly would be a catastrophe for the community.

In such an event there certainly would be a meeting of civic leaders and public officials to make plans to prevent a recurrence. The problem doesn't lose the same significance simply because it is spread out over the days and months of the year.

Examples

A few examples of projects carried out in Dallas may be illustrative. Dallas was the second large city in the nation to install parking meters. Oklahoma City was first, where the parking meter was invented. Our citizens now recognize the true worth and value of the meter as a means of increased car turn-over and scientific regulation of parking.

How different when the idea was new. The motorist couldn't conceive of a paid hitching post for his vehicle! Incidentally, the installation of parking meters was one of the first major tasks of the Citizens' Traffic Commission. It spent many hours of research in trying to determine if the public would accept them. Merchants, newspaper people, delivery services, public officials and others were

called together for meeting after meeting and, in the end, the public as well as the officials agreed on a six months' trial installation.

They are now permanent. Not only have they performed a good job of regulating parking, but have produced over $2,500,000 since their installation, and currently $24,000 a month.

Since that time the magic words "installation and trial" have been used on nearly every project contemplated. Most people, if properly approached, are willing to give a fair trial to a radical traffic change.

Another instance was the adoption of an anti-ticket-fixing policy. Ten years ago ticket-fixing was a recognized and well cherished prerogative of certain officials and department heads. No satisfactory enforcement program could even be begun until this evil was abolished. A proclamation was prepared, the commission asked the city government to announce a public policy on ticket-fixing and thereby served notice to motorist, citizen, court, department heads, and to its own body that effective as of a given date, ticket-fixing was out.

It has been out ever since. Organization representatives on the commission were asked to quickly secure resolutions of endorsement and support and send them to the municipal governing body. That body thus heard a new theme in politics, the people wanted better public safety.

Another forward step was taken when an agreement was reached to set up a well-staffed traffic engineering department in the city, reporting directly to the city manager, and give it a substantial annual budget. One of the first recommendations by that department to the Traffic Commission was to secure public approval for several one-way streets.

Not one existed in Dallas at the time. The first "feeler" public announcement brought opposition. The commission went to work, held meetings, and again used the magic key words "installation and trial" for sixty days. Not one voice has since been raised for repeal.

The Corporation Court building in the early days came under the category of "a hole in the wall." Public support and official action were secured for the building and equipping of a fine municipal court building. The building and improved decorum have produced wholesome respect for all phases of traffic law enforcement.

Incidentally, the by-product of a strong public-supported enforcement program, revenue from fines, has produced funds in sufficient amount to provide for more police officers, more street improvements, traffic signal changes, speed zoning, additional funds for traffic engineering, and traffic education.

Recognizing the need for public education in traffic, the city set up a Bureau of Traffic Education with a $25,000 budget. The director of this bureau serves as executive secretary of the commission. Thus the city, in the public educational field, is assuming its rightful responsibility. The public appreciates this and frequently in varying ways expresses approval to the city administration.

By use of the same magic key words "installation and trial" and the securing of public support, additional steps have been taken such as more one-way streets, rush hour parking bans in the downtown area, Juvenile Traffic Court, mass transportation improvements, and truck re-routing.

Winning Support for Police

One effective method of winning public support of police efforts is the annual Police Awards Banquet where certificates and trophies are given for outstanding work by individual police officers. At these annual affairs it is inspiring to see 300 traffic police officers, youthful, fine-looking, well uniformed, rise in a body to be saluted by 400 civic persons from various areas and organizations from a cross-section of the life of the city.

This annual affair has been carried on for four years and has been attended by different civic representatives each year. There is an entirely different conception of the police officers in Dallas today. The chief receives hundreds of letters a year from citizens who are quick to express their appreciation for the courtesies extended, despite the fact that some may have been given tickets. This annual award program was adopted after the chief inaugurated a seven weeks' eight-hour day training program for new recruits after they had been selected through Civil Service.

Each police graduating class has its own class president, and each class is graduated into service at some regular noon meeting of a major service club. The Traffic Commission pays the expenses for

each of these occasions. There the story is told of the intense training which these men have had. The tasks assigned to them are vividly portrayed. The program is broadcast. Graduation certificates are presented by the Mayor. Hundreds who have witnessed these graduating ceremonies are high in their praise.

Driver-Training in Dallas Schools

A few years back, the need for behind-the-wheel driver training in the schools became apparent. The commission could have paid the expenses of one or more of its members and sent them to the National Safety Congress or other national educational meetings where the plan of driver training was discussed in order to get first hand information on what should be done in Dallas. These men could have come back and made recommendations to the school authorities, but that would have been second hand.

Instead, the commission paid the expenses of the school authorities and sent them to these meetings. It even paid their expenses to some of the major citics which had already installed driver training programs. When these school people returned they were inspired. They knew the public wanted driver training. Today every high school in Dallas, including the two negro high schools, have behind-the-wheel driver training, with the new automobile dealers of Dallas providing training cars for all of the schools.

Dallas has recently completed the first section of the twenty-one million dollar major expressway extending across the city. The commission, joining with the highway committee of the Chamber of Commerce, played a vital part in the opening ceremonies incident to dedicating this highway to public use. Particular effort was made to make it a lavish affair. It brought out over 15,000 citizens. One of the major objectives was to bring about a public consciousness and appreciation of better and more street improvement projects.

Results

Certain success in many traffic fields has been attained. Deaths and injuries have been materially reduced. Dallas ranks among the top

five cities in its population class. Automobile insurance premiums are lower than in other large Texas cities. Considerable improvement has been made in traffic flow.

There is so much to be done in the future that the accomplishments in the past look small in comparison. Many of these new plans are now in the immediate offing. Public officials are depending on the Traffic Commission to secure the necessary public support, including approval for certain bond issues.

Much has been learned about public opposition and how to overcome it, about municipal dealings, police and court problems, the science of traffic engineering, school training, and city planning. More people are closer to municipal problems because they have been exposed to them. By reason of attendance at various kinds of meetings called primarily for traffic matters, civic leaders have met and visited with municipal officials, discussing other affairs of community interest.

Fortunately Dallas has a city council-manager form of government. It is sponsored by sound business interests, conscientious citizens, and those who desire honest, clean, efficient administration. It definitely is not a political government as such at this time. It is run on merit.

This has been of great value in bringing about traffic improvements because the commission has not had to fight politics to any great extent. The commission is an independent body, incorporated under the laws of the State of Texas. It enjoys close friendship and the confidence of all of the public officials with whom it works.

A Traffic Administration Plan Series Part One: Local Leadership

WILBUR S. SMITH
Technical Adviser, Eno Foundation

SOUND organization and administration of local traffic programs are essential. Though many factors are involved, fundamentals always stand out.

The purpose of this and subsequent articles on the subject scheduled to appear in *Traffic Quarterly* is to discuss fundamental and basic requirements for effective municipal traffic activities. The need for strong, continuing leadership is discussed here. Elements of a balanced and coordinated program; professional and technical requirements; and, ways of developing and providing community and financial support will be treated later.

It is impossible to say which of these components of traffic administration is most important, or which should be developed first. As in all forms of public endeavor effective leadership is a major essential. From proper leadership will come the necessary organization and administration. Like any major social reform, some person, or small group, must take the lead and push to achievement.

An increasing number of traffic problems have developed as motor vehicle registrations and uses have grown. Everyone is close to traffic and has become a part of this motorized era. The growth of automotive transportation is evidence of advances in our way of life and of improvements in our general standard of living. No one would want to retard these advances, yet traffic presents numerous problems, particularly to city business districts. It therefore becomes a key responsibility to find workable ways of adjustment and operation so that these activities are carefully articulated to all others of the city.

Traffic Administration Complicated

Demands on the government of a modern city are numerous and of great variety. They are rapidly increasing. Surveys reveal that a

city's government might have responsibility for several hundred functions. Traffic is but one As one among many, as one of the newest, and as one of the most difficult, it must be expected that traffic requires the primary attention of municipal legislative and administrative bodies.

Needs are accentuated by another condition. Many agencies and units of government have a part in diverse traffic affairs. Few municipal offices, agencies, or boards do not have an interest in some phase of the traffic problem. A surprisingly large number have direct traffic responsibilities.

Everyone, it is said, is a "traffic expert," and traffic iils are like the common cold--everybody has a remedy, yet even the doctors don't know a cure. This creates another factor that complicates traffic organization and administration and that accentuates the needs for leadership. Leadership is essential in every sphere of public activity, but in traffic it is most needed because so many people "know the answers." On traffic matters, a mayor, a councilman, or other key official may act casually, yet with personal satisfaction and confidence, when they would never consider parallel actions in other areas of public safety and welfare. Elected officials rarely set themselves up as experts in fire prevention, sanitation, public health, and *other* such fields, but most of them will readily prescribe remedies for *traffic* ills. Public officials have not yet fully recognized the values of technical skills, experience, expert analysis, and facts in traffic.

Personalities will always influence traffic actions because the automobile is such an important part of everyone's life. Rather than look upon these personal interests as all negative, attempts must be made to convert them to positive influences to strengthen the traffic program under a planned and intelligent leadership.

The size of the city and local conditions contribute to the complexity of the problem. A major department of traffic that can do a splendid job of leadership in a large city may be impossible of economic justification in most cities. The very magnitude of the problem fluctuates. Requirements of traffic organizations vary from city to city, so that plans and activities must be formulated for each at least insofar as details are concerned. Faced with these complications poor leadership, or lack of direction, will be apparent.

Leadership Aims

Out of the complicating factors of traffic administration strong leadership must emerge if a city is to cope effectively with mounting traffic demands—demands that should become assets rather than city liabilities.

The person or group assuming the leadership must be *qualified*. They need not be "traffic professionals," but in traffic matters they must have abilities that exceed those of the average citizen. The evils of everyone's being a traffic expert cannot be over-emphasized. Only those qualified can formulate adequate programs and see them through in a logical fashion.

Attention to traffic affairs must be *sustained*. This means it must come from other than elected officials. Yet it is the responsibility of those elected to take the steps necessary to set the program in motion and to make it possible in the first place. Those elected to public office should carry out the majority wishes of the public, but they should not inject their personal ideas and remedies into the laws, policies, and practices of the city.

A distinction must be made between the direction of general and technical affairs; between political and administrative considerations. A two-sided situation develops. Sustained leadership will provide a means of informing and educating the elected officials who are usually not professional people, and the elected officials will maintain a democratic balance between traffic and other functions of the government. Continuity is needed, so that the traffic program will not be ruined by each local election. Persistence and perseverance existing over a long period of time are required to achieve many traffic goals.

Comprehensive leadership will concern itself with both the *formation* of policies (politics included) and the administration and *execution* of policies, even though the two must be separated in application. This brings forth the requirement that the direction of traffic activities requires broad thinking and abilities. This doesn't mean that the plans for leadership must be so broad and ideal as to make them impractical of application. On the contrary, it must be

remembered that many *ideals* of public administration never become a reality.

Sometimes the leadership is not as *sincere* as it appears. There are those cases in which a city official, or officials, may create the impression that top-flight attention is being given to traffic, but where in reality the impressions are false. Recently, the mayor and city officials created a new traffic position and set high standards for the office. Immediately the same officials appointed a man far short of the announced qualifications. It is a favorite political trick to write high and apparently specific standards and then look for ways to circumvent them.

Through proper leadership the city's traffic program will be kept *modern* and up-to-date. Wasteful, ineffective and antiquated methods will be detected and corrected. Often they exist because the persons close to them have got into a rut. Technicians often overlook considerations of public policy. They need outside viewpoints and broad thinking to keep astride new developments and needs.

Leadership is required to *advise* not only the elected officials, but also the public. Many criticisms have been leveled at city traffic activities. The public has become disgusted with "spot" attention, with "drives," with haphazard treatments, with inadequate attention, and with the many other commissions and omissions which inevitably develop in communities without effective traffic leadership.

It is necessary in traffic, as in other fields of public administration, to subject individual problems and needs to thorough analysis so that the factors entering into them can be clearly determined. The decisions in sound leadership will therefore be based on surveys and facts. For example, a traffic leader would be a poor one if all his decisions were based on complaints—with or without investigations.

The traffic technicians and workers are limited as to what they can do by the support they receive from top administrators. Directly, or through established leaders, they have a responsibility to show the values of their work and significant results to the administrators. They cannot stand aside and let matters take care of themselves. The technicians may be able to sell their work to the administrators, but

they often fare better if some other officials or some group takes over the job of selling the program to legislative bodies and to the public.

Ways of Achieving Leadership

Desired support, planning, direction, and coordination of the traffic functions can be achieved in several ways. An administrative official, such as the city manager or the head of a key department might assume the role. It might become a collective function through the medium of an official commission. An unofficial, or advisory board or committee has in some cases provided the leadership. Regardless of the plan, interest and support of elected officials and the public must be recognized and continuously sought.

Administrative Officials—Sustained leadership must come from someone other than an elected official. Usually it is from a person engaged directly in traffic. But, there are other ways. Under a Manager form of government, the problem of traffic leadership can be simplified. As the business head of the municipality, it is a logical procedure for the city manager to provide the leadership. This is desirable because he is familiar with all city affairs and needs, he is in an excellent position to maintain the proper contacts with elected officials, and he can directly coordinate the traffic affairs of diverse city agencies. He will provide all the continuity and direction required to get the job done.

Several prominent city managers, in recent discussions of the problems of cities have placed finance first and traffic second. Such prominent ranking of traffic affairs insures a study of the problems involved and planned actions to correct them. When a city is fortunate enough to have a manager who makes unbiased, relative, and factual appraisals of traffic conditions, it is likely that the manager will furnish the desired leadership.

When there is not a city manager, or when the manager fails to perform the task, other key officials may be called upon; or better, they may on their own initiative assume traffic leadership for the community. It is entirely logical that some department head, whose work is primarily in traffic, should "spark-plug" the activities. Considering the work of various departments in transportation, it is

likely that the task will fall upon the chief of police (or some other enforcement official), or upon the traffic engineer.

Of all agencies of city government, the traffic engineering unit is usually more exclusively concerned with traffic than any other—even the police. For this reason, the traffic engineer may be the best one to lead the city's entire traffic program. As a mayor recently said, "Traffic needs someone to think and deal with it exclusively. Our traffic engineer does this well."

Again, a traffic engineer or an enforcement official can become the key figure in a city's traffic program. This brings us to the "hen or egg" proposition! Can we have the strong traffic engineer or traffic police executive without first having had leadership? Most likely someone, or some group, had to develop a degree of leadership in order to get a traffic engineer appointed or to get proper police consideration for traffic.

But, such developments don't usually indicate the strong and broad leadership advocated. If the needs can be pointed out and the limitations determined the proper type organization will usually develop. Through leadership, the need for traffic engineering and other aspects of traffic administration and organization will be recognized.

Some cases are known where other officials have directed effective traffic activities. These include city engineers, planning officials, educators, and administrative assistants. As a rule, however, such persons are so occupied with other duties that they are unable to devote enough time to traffic to develop and operate an effective program.

Official Commissions—A currently popular method of establishing leadership in traffic is to create a commission or committee of key city officials. The method seems particularly suited to large cities.* Under this plan, heads of departments having relations with traffic matters make up the Traffic Commission. The departments include police planning, public works, finance, judiciary and traffic engineering.

* Such a commission was created in New York City early in 1948. One has operated in Detroit for many years.

The commission may be granted administrative powers of regulation and control by the legislative arm of the city. Recommendations of the body are usually followed by the administrative and legislative officials. While the primary function of such groups is to coordinate traffic activities, it is obviously possible for the body to assume all the requirements for traffic leadership in the community. Often the key leadership can be traced to the chairman or staff director of the commission.

Advisory Groups—Some cities have established traffic advisory groups. They differ from the commissions just discussed in that they may consist wholly or partially of appointed citizens or civic leaders. From the strict standpoint of leadership these agencies are probably more concerned with it than are the commissions of city officials. Anyway, the advisory groups usually give more attention to such leadership requirements as "promoting," "supporting" and "developing" traffic affairs than to coordinating and executing them. (Plans for advisory committees will be discussed in detail in a later article of this series.)

The powers of these groups are limited. They act only in an advisory capacity, but they can do much to bring about needed action by elected officials and to develop public and other support.

With all types of traffic commissions and boards, there is the danger that members will become self-styled "experts." They might become so cock-sure as to preclude group actions and factual approaches.

Sometimes the traffic activities of a city are closely related to those of nearby communities or to a metropolitan area. The advisory groups can be extended and made metropolitan traffic committees. In this way, they provide leadership for the whole area.

Sustained Leadership Supported by Executive Leadership

The point has been made that a sustained leadership, by some person or persons, other than those elected, is essential to a good city traffic plan and program. Such leadership depends on the support of the executive head of the city and on the agreement of a majority of the

legislative body. Elected officials come and go, but they can contribute essential leadership while in office. They can initiate activities their successors must continue.

Many of the most active, adequate and effective urban traffic programs can be traced directly to the interests and efforts of a mayor or a single elected official. In some instances the programs are comprehensive, including all major aspects of traffic; in others, they embrace only one or two key parts, such as parking, expressways, or enforcement. Some of these programs have been reported in the *Traffic Quarterly* by the executives responsible for them.

City traffic problems need strong sustained leadership. They also require the support of elected officials.

A New Study of Urban Stop Signs: A Volume Warrant

MORTON S. RAFF

When Mr. Raff wrote the following article, he was a Research Assistant at the Bureau of Highway Traffic, Yale University on a grant from the Eno Foundation. This article presents some of the highlights of a year-long study which was conducted jointly by the Eno Foundation and the Yale Bureau, in which Jack W. Hart of the Foundation staff collaborated with Mr. Raff. Previously Mr. Raff had been a mathematician for the Navy Department in Washington. A book on a volume warrant for urban stop signs is planned for early publication by the Eno Foundation.

OF ALL the devices to regulate traffic on our streets and highways, the Stop sign is one of the most familiar. Stop signs are inexpensive in comparison with other traffic control devices, and they carry a clear and widely understood message.

Readers of the TRAFFIC QUARTERLY need not be told the advantages of uniform practice in applying and enforcing traffic regulations. A consistent set of standards for choosing the intersections at which Stop signs are to be used is helpful to the motoring public in two ways. Not only does a uniform policy give the average driver an idea of the physical or traffic conditions to expect at a Stop sign; uniformity appeals to his sense of fairness and increases the likelihood that he will obey the sign.

In order to develop a set of conditions which warrant Stop signs it is necessary to consider what Stop signs do. Legally, a Stop sign requires every driver who approaches it to bring his car to a stop and to remain stopped until it is safe to proceed. From a traffic engineering point of view, the use of Stop signs at appropriate locations can (1) reduce accident hazards and (2) facilitate orderly movement of traffic.

The problem therefore is to develop a set of uniform standards—traffic engineers usually call them warrants—prescribing the conditions under which Stop signs ought to be used. A Stop sign has no

value unless it is observed; hence the warrants must seem reasonable to most drivers.

Inadequacy of Existing Warrants

The Manual on Uniform Traffic Control Devices,[1] in the most authoritative statement of the warrants now in use, lists seven conditions warranting Stop signs. These include main roads, state routes, and through streets. Stop signs are recommended for unsignalized intersections in signalized areas and for unsignalized locations where two main highways come together. The Manual also refers to traffic conditions as distinguished from the mere classification of roads and streets—"intersections where high speed, restricted view, or serious accident record indicates a need for control by the Stop sign."

No numerical values are listed for Stop sign warrants, although traffic *signal* warrants in the same manual are literally studded with specific numerical recommendations. Knowledge about traffic behavior at unsignalized intersections was apparently insufficient to provide numerical Stop sign warrants at the time this manual was written.

Numerical Stop sign warrants do exist, based on the danger of accidents at blind intersections. These warrants use the concept of a maximum safe approach speed. Any intersection where the critical speed is less than eight miles per hour warrants a Stop sign. Several different sets of assumptions, all of them highly artificial, have been used to develop warrants of this type, and the results vary considerably with the particular choice of assumptions.[2]

Object of the Present Study

No published material for a numerical warrant based on the delaying effect of Stop signs appears to exist. The present study undertakes to provide such a warrant, especially for urban locations, because a

[1] *Manual on Uniform Traffic Control Devices for Streets and Highways*, prepared by a joint committee of the American Association of State Highway Officials, the Institute of Traffic Engineers, and the National Conference on Street and Highway Safety. Published by the Public Roads Administration, 1948. Pp. 19–20.

[2] The methods of determining safe approach speeds are explained and compared in the Traffic Engineering Handbook (published by the Institute of Traffic Engineers and the National Conservation Bureau, 1941), pp. 192–197.

great many urban intersections need Stop signs to move traffic with greater efficiency. Because of time the study has been limited to developing a Stop sign warrant for urban right-angled intersections not located on arterial streets. The reason for excluding arterial street locations is that such Stop signs are erected as part of a general plan without reference to the traffic conditions at each particular intersection.

The warrant to be discussed is for the conventional *pair* of Stop signs on the minor street, not the more controversial four-way stop. There is a danger in using too many Stop signs. Regulatory signs are useful only insofar as they are obeyed and Stop signs at places where stopping is unnecessary encourage violation of all Stop signs, the necessary as well as the unnecessary ones. It is important therefore to guard against their excessive use.

Warrant Criterion

Legally, Stop signs require every side-street vehicle to make a full stop before entering the intersection. In practice however their effect is to assign the right-of-way steadily to the main street instead of permitting the give-and-take which would otherwise occur. In other words, the Stop sign imposes a delay on every side-street car in order to let the main-street traffic pass through the intersection without delay.

This fact can be used as the basis of a warrant criterion. If one of the two streets at an intersection should take precedence over the other street, it is reasonable to install Stop signs when at least half the side-street cars would interfere with the main-street traffic in the absence of some kind of control. At a Stop sign installed according to this criterion, a side-street driver will know he has less than an even chance of being able to cross without having to wait for a main-street car to clear the intersection first.

Method of Field Observation

The method of taking field data had to be one in which the following traffic measurements could be made:

FIGURE 1. The Graphic Time Recorder (Courtesy U. S. Bureau of Public Roads)

1. Main-street volume.
2. Side-street volume.
3. Times of all arrivals and departures of cars on both streets.
4. Number of delayed cars on the side street.

It was also important that the apparatus be inconspicuous, in order not to distort the normal traffic behavior by attracting undue attention.

The required measurements, especially the third one, suggested the use of some device that would make a continuous record. Basically there are two kinds of apparatus for this: (1) a motion picture camera, and (2) a graphic time recorder in which one or more pens write on a moving chart. Both were considered for this study.

A motion picture camera modified to take pictures at the rate of 88 per minute instead of the usual 16–24 per second has been used effectively in many traffic studies.[2] The camera has two important advantages over most other methods. First, its record is completely objective, unaffected by the reaction time or the snap judgments of the observers. Second, the camera can record complex traffic situations as easily as simple ones, because it merely photographs whatever happens to be in its field of view.

There are serious drawbacks to the camera however. Pictures have to be taken from some high point overlooking the intersection, such as a tower or tall building, and many intersections needing study do not have suitable vantage points for mounting the camera. Moreover poor light conditions or leaf-laden trees can interfere greatly with an otherwise satisfactory vantage point.

These drawbacks were considered important enough to disqualify the camera for the field work of this study.

The alternative device is the Esterline-Angus graphic time recorder (see Figure 1). This machine has a small electric motor which drives a roll of graph paper past a bank of twenty pens at a constant speed. Each of the pens can be pulled out of its normal position by means of a solenoid which is energized by pressing the appropriate telegraph key. Thus it is possible to follow as many as twenty different simultaneous operations with the machine.

[2] See, for example, the article *Traffic Performance at Urban Street Intersections*, by Elroy L. Ericksen, in the July 1947 TRAFFIC QUARTERLY.

In using the graphic time recorder for this study, one pen was assigned to each of the two directions of travel on the main street, while several pens were assigned to each direction on the side street in order to keep track of cars which piled up at the intersection. In addition, one pen was used to indicate the time shown by a stopwatch, as a check on the speed of the motor.

Two observers sat in the back seat of a parked car, with the graphic time recorder between them. Used in this way, the machine attracted almost no attention whatever, and was operated satisfactorily both at night and in cold weather (with the aid of the heater in the car).

Locations Used

About fifty-two hours of observations were made at four intersections in New Haven, Connecticut. All four locations were intersections of a minor side street with a through street. Intersections of this type were chosen in order to study the delaying effect of Stop signs on the traffic movement and thereby to determine the volume conditions under which such delays would be justified.

Critical Lag

To predict the percentage of side-street cars which can expect to be delayed at an intersection, there is a third quantity which must be known, in addition to the main- and side-street volumes. This quantity, which is here called the *critical lag,* is the car-free time interval which a typical side street driver needs in order to enter the intersection.

To illustrate this with an example, consider a hypothetical intersection at which the critical lag is five seconds. If a side-street car reaches such an intersection when the next main-street car is *four* seconds away, the chances are that the side-street driver will wait until the main-street car has passed before he enters the intersection. On the other hand, if the main-street car is *six* seconds away, the side-street driver will probably enter the intersection immediately, without waiting for the main-street car to go by.

The effect of the size of the critical lag on the percentage of delayed cars is evident. An extreme case: if the critical lag were zero,

there would be almost no delayed side-street cars, whereas a critical lag as long as one minute would delay nearly all the side-street cars even if the volumes were small.

Actually, the critical lags at the four intersections had values ranging from 4.6 to 6 seconds. At each intersection the critical lag remained constant as the volumes went up and down, but there were marked differences in critical lag between one intersection and another. The most probable explanation of these differences is the difference in sight conditions at the various intersections.

Two Types of Delay to Side-Street Cars

The next step, after determining the critical lag at each of the experimental intersections, was to find out what proportion of the side-street cars were delayed, and how this proportion was related to the traffic volumes on the two streets. The object was to develop a formula from which the proportion of delayed side-street cars could be predicted when the critical lag, the main-street volume, and the side-street volume were known. It was thought at first that the number of lanes on each street might also have to be taken into account, but this turned out not to be the case.

Side-street cars at a "Stop" intersection can be delayed in two different ways. Consider first the situation at a signalized intersection rather than one controlled by Stop signs, because the principle is a little easier to grasp when presented in this way. To make the illustration even clearer, suppose that our signalized intersection is a right-angled crossing at which all turns have been prohibited, so there are no delays caused by vehicle conflicts arising out of turning movements. A driver approaching such an intersection is delayed in either of two circumstances:

1. If the light is red when he gets to the intersection, he is stopped regardless of other traffic.
2. If the light is green when he gets to the intersection, he is sometimes stopped by other cars in front of him which have been stopped by a previous red light and are slow in getting started.

The two types of delay may be called (1) right-of-way delay, due to assignment of the right-of-way to the other street, and (2) sluggish-

ness delay, caused by the sluggishness with which a line of stopped cars gets into motion. If the stopped cars could start up instantly when the light turned green, there would be no sluggishness delay. In such a case, the proportion of delayed cars could be computed directly from the timing plan of the signal, without direct reference to the traffic volume on either street.

The same two types of delay are found at an intersection controlled by Stop signs. The right-of-way delay in this case is due to the fact that the intersection is blocked to side-street traffic whenever a main-street car is nearer the intersection than the critical lag. The sluggishness delay is the same as at the signalized intersection.

Percentage of Delayed Side-Street Cars

At a signalized intersection, the proportion of cars in a single traffic stream subject to right-of-way delay is the proportion of time during which the signal is red. At Stop sign intersections it was found that the proportion of side-street cars subject to right-of-way delay is a function of the critical lag and the main-street volume, and is independent of the side-street volume. The relationship is as follows:

$$p = 100\ (1 - e^{-NL}), \qquad (1)$$

where p is the percentage of side-street cars subject to right-of-way delay, e is the base of natural logarithms (about 2.718), N is the main street volume, and L is the critical lag. This formula can be derived from the mathematical theory of probability, and is based on the assumption that the traffic on both streets is distributed in a random fashion. This assumption was surprisingly well borne out in practice.

Formula (1) refers solely to the right-of-way delay, and therefore gives the total delay only when the amount of sluggishness delay is negligible—that is, when there is practically no side-street traffic. For side-street volumes which are large enough to make the sluggishness delay an important consideration, it is necessary to devise a correction to formula (1) which takes the sluggishness into account. This was done by means of empirical observations.

At each of the four intersections the observation time was divided into fifteen-minute periods for the purpose of analysis. The

main-street volume, the side-street volume, the number of delayed side-street cars (counting both kinds of delay), and certain other quantities were tabulated for each of these fifteen-minute periods. The percentage of delayed side-street cars was then plotted against the main-street volume, with separate graphs for different ranges of side-street volume.

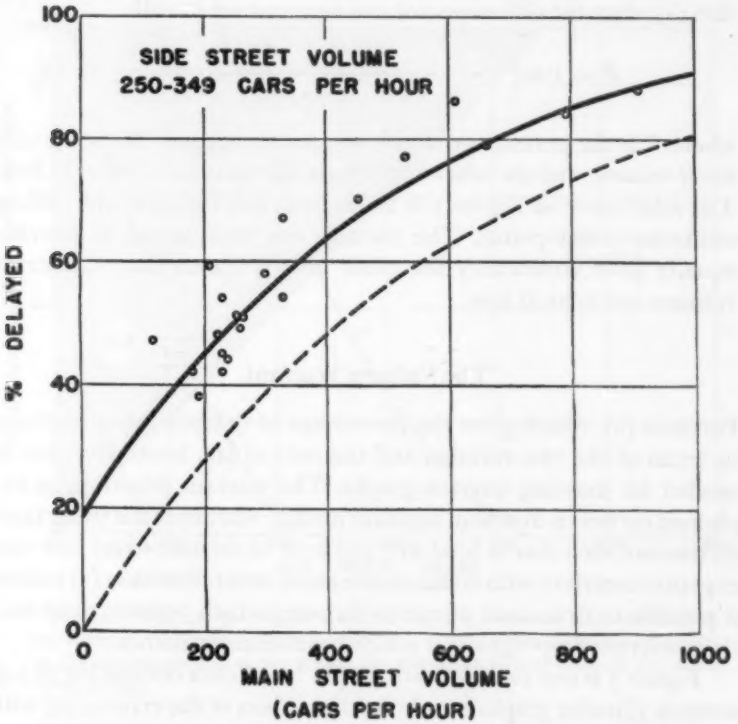


FIGURE 2. Percentage of delayed side-street cars. Each point represents one fifteen-minute period of observation. The dashed curve is the crude formula (1) of the text; the solid curve is the more refined formula (2).

Figure 2 is one of these graphs. Each of the points shows the percentage of delayed side-street cars and the main-street volume during one fifteen-minute period. This particular graph includes only those fifteen-minute periods during which the side-street traffic flowed at a rate between 250 and 349 cars per hour.

The dashed curve in Figure 2 was computed from formula (1), which gives the percentage of side-street cars which are stopped *because of right-of-way delay*. Since all the points are above this curve, it is evident that there is an appreciable amount of sluggishness delay in addition to the right-of-way delay. A formula has been developed which takes both kinds of delay into account, and reduces to expression (1) when the side-street volume becomes very small:

$$P = 100\left\{1 - \frac{e^{-2.5Ns}\, e^{-2NL}}{1 - e^{-2.5Ns}\,(1 - e^{-NL})}\right\}, \qquad (2)$$

where P is the percentage of side-street cars delayed, Ns is the side street volume, and the other letters have the same meaning as before. The solid curve in Figure 2 is taken from this formula, and closely conforms to the points. The formula has been found to provide equally good conformity for other graphs for various side-street volumes and critical lags.

The Volume Warrant

Formula (2), which gives the percentage of delayed side-street cars in terms of the two volumes and the critical lag, is exactly what is needed for drawing warrant graphs. The warrant criterion, as explained earlier, is that Stop signs are needed whenever the traffic conditions are such that at least fifty per cent of the side-street cars can expect to interfere with traffic on the main street. Formula (2) makes it possible to draw a set of curves showing which volume combinations warrant Stop signs and which combinations do not.

Figure 3 is one such warrant graph, based on a critical lag of 5.9 seconds. (Similar graphs based on other values of the critical lag will appear in the forthcoming book.)

The main-street volume is plotted along the horizontal axis, the side-street volume along the vertical axis, and the three curves indicate the volume combinations for which 25 per cent, 50 per cent, and 75 per cent of the side-street cars can expect to be delayed. A volume combination warrants Stop signs under the volume warrant, if and only if it falls to the right of the 50 per cent curve.

For example, an intersection having 400 cars an hour on the

main street and 200 cars an hour on the side street would warrant Stop signs, because the percentage delayed would be more than 50—about 60, to be exact. If the volumes were cut in half, however, to 200 cars an hour on the main street and 100 cars an hour on the side street, there would be no need for Stop signs, since the per cent delayed would be only 34—well under 50.

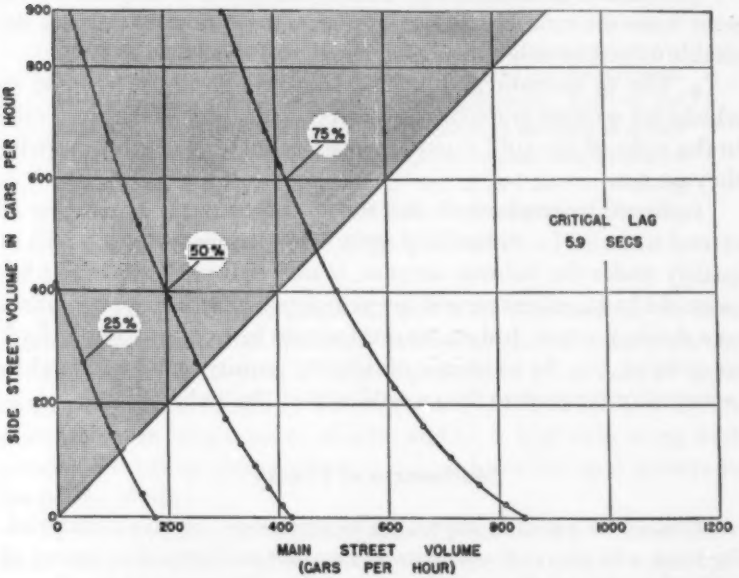


FIGURE 3. Warrant graphs, for a critical lag of 5.9 seconds. The curves show the volumes for which 25%, 50%, and 75% of the side-street cars are delayed. In the shaded portion of the graph, the side-street volume exceeds the main-street volume.

Clearly it is not the ratio of volumes but actual values that determine whether or not the warrant is satisfied. In application, it is not recommended that a Stop sign be installed on the basis of a one-hour volume count. Rather, it would be warranted under the criterion of percentage delayed, if an average day contains eight hours during which the volumes are such as to delay at least fifty per cent of the side-street cars.

The procedure of using the warrant consists, then, of four steps:

1. Choice of main and side streets. Usually the street with the heavier traffic, or sometimes the wider street, should be chosen as the main street.

2. Determination of critical lag. The critical lag for the particular intersection is measured by a procedure which will be explained in detail in the book.

3. Volume counts. The volumes can often be counted at the same time the critical lag measurements are being made. It is desirable to have hourly volumes for the period 6 A.M. to 10 P.M.

4. Use of warrant graph. The volume figures are applied to whichever warrant graph has the correct critical lag. If the point falls to the right of the 50% curve, Stop signs are warranted; otherwise they are not.

It should be emphasized that the volume warrant *is only one* of several warrants for urban Stop signs. Even if an intersection fails to qualify under the volume warrant, it may still need Stop signs because of a bad accident record, severe sight obstructions, or a location on a through street. Judgment must always be used in applying any set of rules, but the existence of definite requirements will lead to more uniform practices than would exist in their absence.

Mathematical Theory

In addition to a greatly expanded treatment of the above material, the book will also contain a chapter on the mathematical theory of traffic behavior at "Stop" intersections. This chapter will develop in a methodical way the theory of a single traffic stream, recapitulating the work of Adams[4] and of Greenshields, Schapiro, and Ericksen,[5] and carrying it somewhat further. With this as a foundation a rudimentary theory is developed for the interaction between *two intersecting* streams of traffic. This synthesis of two randomly distributed traffic streams is believed to be original, and it is hoped that others will be stimulated to carry the development still further.

[4] William F. Adams, *Road Traffic Considered as a Random Series.* The Institution of Civil Engineers Journal, November 1936. Pp. 121–130.

[5] Bruce D. Greenshields, Donald Schapiro, and Elroy L. Ericksen, *Traffic Performance at Urban Street Intersections.* Technical Report No. 1, Yale Bureau of Highway Traffic, 1947. Pp. 73–83.

Some Road-User Characteristics in the Traffic Problem

EARL ALLGAIER

Mr. Allgaier is an engineer in the Traffic Engineering and Safety Department of the American Automobile Association. He has been associated with this department of A.A.A. since 1936 except for the period from 1941 to 1943 when he developed tests for the classification of enlisted personnel for the War Department. For the last three years most of Mr. Allgaier's work has been devoted to driver training. This has included the assignment of dual control cars to high schools and the supervision of high school teacher-training courses. Mr. Allgaier also has worked on the development of testing devices and on the pedestrian protection program.

DRIVERS in the United States constitute an estimated 34 per cent of the population. Probably more than 50 million drivers use our highways. These drivers include persons of practically all ages, races, and degrees of ability. In some cases, children ten and eleven years old drive farm tractors on state and U. S. highways along with persons seventy or eighty years of age, and middle aged drivers in the prime of life.

Because of this wide variation among individuals, we must know more than the nature of the average driver. It is more important that the differences be analyzed with a view toward improving or eliminating those drivers who are likely to cause the most trouble on our crowded highways. Unfortunately, at the present time we lack sufficient knowledge of driver characteristics to set up standards which will efficiently remove the unsafe drivers from our highways. At best, the procedures now used eliminate only a few of the potentially hazardous drivers, as indicated by the fact that about 32,000 persons are killed annually in traffic accidents. It is true that some of these deaths are caused by engineering failures in the modern motor car and the highway system. However, such failures are relatively unimportant when compared to the failures of the man behind the wheel.

Age Characteristics

Traffic safety programs must be suited for practically all age groups including mere children and adults 70 and 80 years of age. Over half of all drivers (about 55 per cent) fall in the age group of 20–40 years of age. Approximately 10 per cent are 19 years of age and under, and a very small percentage (about 6 per cent) are in the age group of 60 and over. When comparing the records of various age groups, it is important to consider both the number of drivers in each group and the number of miles driven per year by the individual drivers in each age group. The following table gives the approximate percentage of all drivers falling into each age group and the per cent of the population in each age group that are drivers.

Age Group	*% of All Drivers*	*% of Each Age Group That Are Drivers*
19 and under	10.3	10% (38%)*
20–24	15.0	59%
25–29	15.0	61%
30–34	13.6	60%
35–39	11.6	55%
40–44	10.0	52%
45–49	8.1	45%
50–54	6.2	39%
55–59	4.3	33%
60–64	2.9	28%
65–69	1.7	20%
70–74	0.8	14%
75–79	0.4	12%
80 and over	0.1	3%
	100%	

* Of the group 15 to 19 inclusive, 38 per cent would be drivers if there were no drivers younger than this group.

It is difficult to obtain accurate figures on the number of miles driven by drivers of various age groups. It is reasonable to assume that the persons just learning to drive and the elderly persons drive less per year than the middle aged drivers. One estimate of the relative mileage driven was obtained from interviews of 5,451 drivers who took

a series of A. A. A. driver tests during 1937. While the mileage thus obtained was probably overestimated, there is no reason to believe that one age group overestimated more than another group, so the figures should be of some value in comparing the relative mileage driven by various age groups. These figures would seem to indicate that the annual mileage increases rapidly to about 21 years of age, then levels off and starts to decrease after 50 years of age. The following table gives the average annual mileage for each age group as estimated by the individual drivers.

Age Group	*Annual Mileage Estimated by Drivers*	*Millions of Miles Driven per Fatal Accident*
16	4,700	2.3
17	6,600	3.5
18	7,400	5.0
19	10,200	4.7
20	11,400	5.2
21	14,000	6.4
22	15,000	7.6
23	15,500	9.7
24	17,800	12.7
25–29	16,200	12.2
30–34	16,500	15.7
35–39	16,800	16.8
40–44	16,400	18.6
45–49	15,100	21.9
50–59	14,000	19.7
60–69	10,400	12.1

The young and inexperienced drivers have more than their share of accidents. The above table gives the miles driven per fatal accident by drivers of various ages, taking into consideration estimates of annual mileage and the number of drivers in each age group.

There is naturally a high correlation between inexperience and age since most persons learn to drive while they are young. Therefore, we do not know the relative importance of age and experience in producing the relatively bad record for the young driver and the relatively good record for the older driver. Most limitations on driving are based on age rather than experience, and it may be that experience is equally important. If such is the case, it would be just as

essential to require an experience limit as well as an age limit for an unrestricted driver's license.

Further light is thrown on the fatality records of the various age groups by data from the Texas Department of Public Safety. This information shown in the following table gives the per cent of all drivers in each age group, and the per cent of drivers involved in fatal accidents falling in each age group. Here no consideration has been given to the variation of the mileage driven by the various groups. While only 15.0% of all drivers were in the 20–24 age group, this group had 20.9% of the fatal accidents in Texas.

DRIVERS INVOLVED IN FATAL ACCIDENTS IN 1948 IN TEXAS

Age Group	*% of Drivers in Fatal Accidents*	*% of All Drivers* in Each Age Group*
10–14	.3	10.3
15–19	9.3	
20–24	20.9	15.0
25–29	16.4	15.0
30–34	12.2	13.6
35–39	10.4	11.6
40	9.0	10.0
45	6.4	8.1
50	5.4	6.2
55	3.5	4.3
60	2.9	2.9
65	2.0	1.7
70 and over	1.3	1.3
	100%	100%

* This distribution is an estimate for the country as a whole, but should be a reasonable estimate of the age distribution in Texas.

Sex Characteristics of the Driving Population

When comparing the accident records of men and women drivers, the relative exposure of each to traffic hazards is frequently not taken into consideration. Apparently, women drive slightly slower than men, indicating a greater caution on their part. Of the men and women interviewed, who took a series of driver tests, the average man indicated that he drove 47.4 miles per hour on the open road,

while the average woman driver indicated that she drove 44.7 miles per hour. The average man also estimated that he drove nearly twice as far per year as the average woman driver.

In the general population, men and women are quite evenly divided; however, a larger percentage of men are licensed drivers than are women. A tabulation based on reports from 30 states indicates that about 27% of the licensed drivers are women. If we may assume that these figures are approximately correct, that 27% of the drivers are women, and that the average woman driver drives only half as far per year as the average male driver, then it would appear that about 13% of the driving done on our highways is done by women drivers. This is further confirmed by any casual observation of drivers as they are met on the highway. Even in cases where there are both men and women occupants in the car, the driving is usually done by the man.

According to accident facts, women drivers constituted 6% of all drivers involved in fatal accidents and 9% of the drivers involved in non-fatal accidents during 1947.

Other Individual Differences

Drivers differ also in their knowledge of traffic regulations. In one study of 1,147 drivers selected at random, it appeared that the best scores were made by persons 25–30 years of age. The scores were slightly lower for the older and younger persons. The average scores obtained on a 20-question multiple choice test are shown for each age group below for 1,147 men tested in Wisconsin.

Age	*Average Score on Test*
15	58.3%
16	66.3
17	67.0
18	67.6
19	65.8
20	67.7
21	68.3
22	71.3
23	72.8
24	72.2

Age	*Average Score on Test*
25–29	73.4
30–34	72.6
35–39	69.9
40–49	69.5
50–59	64.1
60–69	61.4

Attitude

It is obvious to laymen and specialists alike that attitude is one of the most important factors in the accident record of a driver. However, it is also agreed that this is one of the most difficult factors to measure, the difficulty being that the real attitude of an individual can be hidden when the individual knows his attitude is being checked. For this reason, attitude tests have not been successful in sorting out drivers with bad attitudes.

One interesting bit of information on attitude was obtained by a simple test consisting of twenty-five statements pertaining to traffic situations. These statements were selected from a larger number of statements given to a group of drivers who had been involved in accidents and another group of forty-nine drivers, selected from each state as being the safest driver in the state. Each item was to be checked as agreeable or disagreeable. The items were selected on the basis of their ability to differentiate between these two groups. This test was then administered to a group of eighty-two adults enrolled in an adult driver training class and 138 college men not enrolled in any driving class. The median score for the college men was twenty-three and for the adults, twenty-seven. Complete tabulation of scores is shown in the following table.

Score on Attitude Scale	*College Men*	*Adults in Driver Training Class*
10	2	
11	2	
12	2	
13	0	1
14	1	1
15	3	3
16	2	1

Score on Attitude Scale	*College Men*	*Adults in Driver Training Class*
17	3	2
18	11	2
19	11	2
20	7	4
21	14	0
22	9	2
23	11*	1
24	9	6
25	10	5
26	9	10
27	9	9*
28	7	6
29	3	4
30	1	4
31	2	7
32	7	3
33	1	2
34		2
35	2	4
36		
37		
38		
39		1
	138	82

* Represents median scores for each group.

While admittedly this is meager information, it does confirm the general feeling that older persons acquire a better attitude than the young driver who has not yet learned the social consequences of his driving habits. Perhaps future research will develop a more accurate measure of this highly important characteristic.

Vision

Since a driver receives by far the most of his information through his eyes, they are one of the most important factors in traffic safety. Recognition of this is indicated by the fact that 44 states require a test of visual acuity for a license. But there is little agreement on the

minimum desirable standard. It is well known that visual acuity at a distance drops off with increased age, especially after the age of 40. A great many people realize this and compensate by obtaining corrective glasses. The extent of this compensation is shown in the following table by the percentage of drivers of various age groups who wear glasses.

Age Group	*Per Cent of Drivers Wearing Glasses*
15–19	11%
20–24	12
25–29	12
30–34	12
35–39	13
40–44	18
45–49	33
50–54	50
55–59	58
60–64	66
65–69	69
70–74	69
75–79	69

These figures are based on 104,952 men and 28,390 women applying for a license in St. Louis, Missouri, during 1942. In general, a slightly larger percentage of women than men wore glasses for all age groups.

Even though many drivers correct or improve their vision with glasses the vision of the average driver on the highway decreases with age. The following table is based on tests taken by 2,450 men including men wearing glasses, if they wore glasses while they drove.

Age Group	*Average Visual Acuity*
15–19	95%
20–24	101
25–29	101
30–34	96
35–39	95
40–44	96
45–49	92
50–59	84
60–69	79
70–79	78

Another visual factor which may be even more important than visual acuity is the ability to see at night. Because there is no test which is both accurate and easy to administer, very little information has been accumulated on either individual variations, ability to see at night, or the relationship of night vision to night traffic accidents. It is a generally accepted fact that the mileage traffic accident rate at night is about three times the daytime rate. The difficulties of night seeing are doubtless a very important factor in this high night accident rate.

The public has been confused on this subject because of reports released by various investigators using various instruments and various standards. In some cases the dividing line between the night blind and normal has been arbitrarily set at such a high point that a considerable proportion of the population is classified as night blind. It is more probable, however, that the ability to see at night varies somewhat like visual acuity. That is, most people have about average ability. Some have better than average ability; some have less than average ability with a very small percentage, which might properly be called night blind because of their inability to see at all in the dark. In other words, there are people who vary all the way from those who can hardly see in the dark to those who can see very well.

This distribution is confirmed by tests made on over 1,000 soldiers at Fort Knox, Kentucky, during 1942. These men were kept in the dark 25–30 minutes and then tested on the Wald Adaptometer, which measured the intensity of a flash of light just visible to the naked eye. The distribution of scores made is shown in the table below. Nineteen units on this scale is approximately equal to one log unit, or in other words, a difference of two readings on this scale of 19 units would indicate a difference of light intensity in the ratio of 1 to 10.

*Scale Reading**	*Number of Persons*
19	1
20	0
21	0
22	1
23	3
24	2

* A high reading indicates a brighter light or a poorer score.

*Scale Reading**	*Number of Persons*
25	6
26	18
27	27
28	54
29	72
30	124
31	155
32	180
33	250
34	247
35	210
36	129
37	126
38	79
39	75
40	39
41	15
42	18
43	14
44	14
45	9
46	2
47	2
48	6
49	1
50	5
--	
59	1
78	1

* A high reading indicates a brighter light or a poorer score.

This distribution seems to indicate that the vast bulk of the population follows a normal distribution, and that a very small percentage of the population is extremely night blind. It also indicates that there is a wide variation among individuals in the light required to see equally well at night. There is a wide difference between those who can see best and those who have poorest night vision.

During the war, a group of 100 young men in good health were tested after 30 minutes in the dark by having them identify black and white stripes. Illumination was increased by moving the source of illumination (radium buttons) toward the target. The two indi-

viduals with the poorest night vision required about ten times as much light as the two persons with the best night vision.

Since these were all young people, generally in good health, it is quite evident that the variation among drivers on the highway would be even greater than this. Only in rare cases does an individual driver know how his ability to see at night stacks up to the general average. For daytime driving we have tests of visual acuity which can be used to screen out the person whose daytime vision is seriously deficient. We do not have practical tests for screening out the people with seriously deficient night vision.

Reaction Time

Vision and reaction time are probably considered by lay drivers as major factors in driving ability, since the ability to avoid an accident frequently depends upon seeing it in time and stopping before a collision results. From the studies that have been made, the correlation between reaction time and various measures of driving ability has been disappointingly low. This is due in a large measure to the fact that the effects of reaction time are covered up by many other important factors. The person who is slow to react may fully compensate for that deficiency by driving more slowly and avoiding traffic situations which require quick reaction. It is altogether possible that if the effect of all other factors could be excluded, then the relationship of reaction time to driving ability would be significant. Yet there are a few facts concerning reaction time which should be considered in traffic safety programs.

There is no one figure which can be used for the average reaction time, since this time depends upon the conditions under which it is measured. The studies which have been made indicate that when the average driver is all set, ready to react, it will take him a little over 0.4 of a second to move his foot from the accelerator to the brake pedal after the appearance of a red light. This is probably the simplest reaction ordinarily encountered in driving. The comparable time for the average driver to press a key with his finger when a red light appears is slightly over 0.2 of a second. But this particular situation seldom arises in actual driving.

In most situations, reaction time is probably far in excess of a simple foot reaction, since the driver is not usually all set to react and he does not know in advance the type of reaction to make. He may have to step on the accelerator or turn the steering wheel to avoid an accident. Because of the wide variety of such situations, ¾ of a second is frequently used as a reasonable figure for the average reaction time in designing traffic facilities. In unusual situations the total time required to make the correct response may be several seconds.

As with many other human characteristics, age has an important effect on reaction time. After about 40 years of age, reaction time starts to increase. As the reaction time increases with age, the driver's experience and judgment also increase, and probably more than offset the handicap of increased reaction time.

Consequently, in spite of increased reaction time, older drivers have a better accident record than younger drivers who have quicker reaction time. It is unfair to penalize a driver for a long reaction time without carefully considering all other factors, since the older driver with slow reaction time is likely to be safer than the younger driver with quicker reaction time.

Reaction time is probably more important from an educational standpoint than it is as a basis of selecting drivers. Too many drivers feel that they can stop on a dime and have no appreciation of the distance travelled while reacting and after the brakes are applied. Stopping distances are frequently grossly underestimated.

A simple device called the brake reaction detonator has been found to be very effective in getting this point across to the average driver. This device mounts on the front bumper of the car and the driver is tested at any speed. The examiner or instructor fires the first .22 blank which marks the roadway and serves as a warning for the driver to make an emergency stop. As soon as the driver hits the brake, a second blank is fired marking this point on the roadway. By measuring between these two chalk marks, the driver is given concrete evidence of his reaction time distance. The measurement from the last mark to the front bumper where the car comes to rest gives the braking distance. This incontrovertible evidence is one of the most effective means of impressing on a driver the distances required for stopping at various speeds.

As traffic situations become more complex and the driver's attention must be divided over a wider field, reaction time naturally lengthens. For this reason, driver training instructors and textbooks must emphasize the importance of concentrating full attention on the driving problem rather than dividing attention by conversation with other passengers and viewing the passing landscape.

The future may see reaction time reduced through changes in car construction which will lessen the time required to move the foot from the accelerator to the brake pedal. Devices have already been developed in which the driver can keep his right foot on a single pedal to control both acceleration and deceleration.

Physical Stamina

The modern car requires far less physical exertion than the cars of two or three decades ago. However, a certain amount of physical stamina is required. After 50, the physical stamina of most drivers begins to decline. One measure of the ability to withstand physical violence is the ratio of pedestrians injured to pedestrians killed, by age groups.

The following table is based on data from 17 states for 1936, 1937 and 1938, involving 16,726 pedestrians who were killed and 205,562 pedestrians who were injured. For the 5–14 age group, 29.8 persons were injured for each one killed while for persons over 65, 3.6 were injured for each one killed. In other words, older people do not have the physical ability to recover after being injured.

Age Group	*Ratio of Pedestrians Injured to Killed*
0–4	20.5
5–14	29.8
15–24	18.1
25–64	9.6
65 and over	3.6

Selection of Drivers

By careful selection of drivers, it should be possible to improve the accident record. Accident reports give some evidence that this is possible. For the 1947 calendar year, the over-all traffic death rate

was 8.6 per hundred million vehicle miles. For all types of commercial vehicles for the 1946–47 fiscal year, the comparable rate was 2.69. Only one class of trucks had a higher rate than 8.6 and that was the For Hire City Trucking, with an accident rate of 11.8 per hundred million vehicle miles. Commercial passenger cars in the eastern area had a rate of only 1.4 and in the western area, a rate of .91. The vast majority of private passenger car drivers do not have adequate training and very few of them are carefully checked before being given an operator's permit. The result is that the over-all national traffic death rate is high.

The Accident-Prone Driver

The accident-prone driver is generally a person who has more accidents than he would normally have according to the laws of chance. The results of studies of accident-proneness are unfortunately affected by the length of time covered in the study. For example, we might take an unusual situation and study the accident records of 1,000 drivers for a single day. We might find that five of these drivers had accidents. The statement could then be made that one-half of 1% of the drivers cause all the accidents.

This illustration indicates the need for studying the records of drivers over a long period of time before defining accident-proneness. This is especially important when considering the cancellation of an operator's permit. If a driver has had a number of accidents in the past and is an accident-prone driver, then he is likely to have a number of accidents in the future. There is justification for revoking his license to drive so as to eliminate the accidents he is likely to cause in the future.

On the other hand, if a man's past accident record is due largely to chance and he is not an accident-prone driver, there is no reason to believe that his record in the future will be any worse than that of the average driver. In such a case, it is not fair to revoke his license.

Probably one of the most complete studies on accident-prone drivers was made under the direction of the Highway Research Board. The accident records of 29,531 Connecticut drivers were studied for the period 1931–1936 inclusive. During this six-year period, 211 drivers had 3 or more accidents each whereas according

to chance only 57 drivers should have been involved in that many accidents.

Further evidence that past performance is an indication of future performance is given in the following table taken from the above study.

ACCIDENT RATES FOR TWO SUCCESSIVE PERIODS OF 3 YEARS EACH

Accident Group 1931–33 *Accidents per Driver*	*Same Groups 1934–36* *Accidents per Driver*
0	.101
1	.199
2	.300
3	.484
4	.700

This would seem to justify giving considerable weight to past experience when employing a driver or deciding whether or not a license should be revoked.

Driver Licensing

In general, drivers are selected by two groups of agencies: Official groups interested primarily in granting licenses only to drivers who will not be a hazard to the general public; commercial organizations who must employ drivers to operate company vehicles. These employees must not only be safe drivers, but they must be able to handle a vehicle with maximum efficiency in order to deliver the most goods at the cheapest rate, all costs considered.

Because of the lack of adequate research information, motor vehicle departments must rely chiefly on the judgment of experts in setting up standards for the licensing of drivers. The fact that these standards vary widely from state to state, indicates that even the experts do not agree on the desirable minimum standards. Visual acuity requirements vary from 20/70 to 20/30 among the states indicating that there is no agreement as to the safe minimum.

A person considered unfit to drive in one state may be given a license in a neighboring state. In most states, drivers are given an examination only on the original application. Their operator's permit

is renewed by application and payment of a fee. In only 3 states are drivers required to take any more than the original examination.

It is a commonly accepted fact that a person's physical abilities decline with age. This decline is especially noticeable after 50 years of age. Thus many drivers who were perfectly capable when they obtained their license at 25 years of age may have serious deficiencies at the age of 60 or 70. Of course, it is possible for the physical abilities of a person 30 years of age to change radically. However, it does not appear practical at the present time to re-examine everybody at regular intervals of time.

The more logical solution seems to be to examine the older drivers and drivers of all ages who indicate they may have some deficiency, such as those involved in accidents or traffic violations. The state of Pennsylvania has made a significant step in this direction by a more thorough clinical examination of drivers who have been involved in accidents or traffic violations. By concentrating on the small group of drivers that are likely to cause more than their share of accidents, the greatest good can be accomplished for the time and money spent.

Drivers of commercial vehicles are responsible for life and property to a much greater extent than private passenger car drivers. Commercial organizations have realized this and have in many cases set up training programs and more rigid requirements for the selection of drivers. Small organizations operating a few trucks or passenger vehicles cannot afford adequate personnel or equipment to do a thorough training and selection job. This need is now met by two types of agencies.

In one case, state trucking associations are establishing portable driver clinics which can be taken from community to community to examine the drivers for small fleets that otherwise could not afford such facilities. These have already been established by state trucking associations in California, Colorado, Florida, Illinois, Missouri, Nebraska, Michigan, Pennsylvania, Oregon and Texas. Projects of this type should be quite successful, provided they are operated by trained personnel and are not used primarily as a promotional scheme.

In a number of instances, private organizations have been set up in large cities to examine commercial drivers for a fee. Operated by

trained personnel, imbued with the idea of rendering a real service and doing a good job, they should be successful and meet an important need. Some of these have not been so operated. Their failure tends to reflect on the over-all driver selection and training program and makes it more difficult for other similar organizations to secure public good will.

Training of Drivers

Driving is a skill like any other mechanical operation. Like any other skill, it must be developed by properly guided practice. Trial and error methods may result in hazardous habit-forming practices. In the past a large percentage of the drivers learned to drive by picking up information of their own, or by receiving a few pointers from a friend who had never been properly trained. The small percentage of people who have received special training is shown in the following table based on polls taken of nearly 8,000 persons attending the New York Automobile Shows.

Method of Learning to Drive	*Per Cent of Total*
Self taught	37.8%
From a friend	28.8
From a relative	19.2
From a driving school	9.8
From an auto salesman	4.4

More and more the general public is beginning to appreciate the importance of proper training. Studies made among high school students indicate that proper training will cut accidents in half. Most of this training is now being given in high schools. At least 3,000 high schools are giving behind-the-wheel training and several thousand additional are giving classroom instruction only.

Training at this age is probably more effective than for any other age group. Interest is high since students are at the age for obtaining driver licenses. They have already developed study habits and are used to receiving formal instruction under trained teachers. Older people generally find it more difficult to take formalized training.

While driver education and training courses are primarily a function of educational institutions, motor vehicle and state high-

way departments have in several cases taken an active part in promoting driver training programs since these organizations realize fully the results of improperly trained drivers.

Special schools for traffic violators, properly organized and staffed with trained personnel, should fill the important gap in the training program by training those drivers who by their records have proved the need for such training.

Private driving schools operated by A. A. A. Clubs and other private organizations meet the needs of those persons who realize their deficiencies and want to learn to drive the correct way but do not have the opportunity of enrolling in high school courses. However, the vast majority of drivers now on our highways, especially those with improper attitudes and those who think they know it all, will never enroll in such schools.

In a great many cases, progressive owners of commercial fleets have conducted their own driver training schools and are able to do an adequate job for their own fleet drivers. The operators of these schools have a personal interest in training their drivers and the drivers have a personal interest in learning to drive properly as their progress and even their job may depend upon the skill they develop in these training courses.

Control of Drivers

Official agencies at present can only hope to reach a small minority of the drivers after they have been licensed. Therefore the quality of driving on our highways will depend largely on the willingness of the individual driver to do his best. General mass education will help in making the average driver conscious of his responsibility. As far as possible, highway facilities must be built which will keep to a minimum the driver's conflict with other users of the highway and provide adequate warning devices of hazards which cannot be removed.

Through enforcement we must attempt to eliminate drivers incapable of driving and those who are capable but by their records prove they will not abide by rules laid down for their own protection and for the protection of other highway users. The extreme penalty

of permanently revoking a driver's license should be used only after it is reasonably certain that he will continue to cause trouble in the future.

We now have available a limited amount of information concerning the nature of the drivers using our highways. Information needed, however, to reduce substantially the 32,000 traffic deaths annually is still insufficient. Money could well be put into research to determine the most effective driver-training methods. More aid is needed to solve the complicated problem of why drivers have accidents. In this field hardly a beginning has been made, probably because of the multiplicity of factors involved and the difficulty of isolating the effect of each one.

Factual Studies Needed in Solving Urban Traffic Problems

PYKE JOHNSON

Mr. Johnson, formerly a Colorado newspaper man, has been President of the Automotive Safety Foundation since 1942. Previously for nearly a quarter of a century he was with the Automobile Manufacturers Association, becoming executive vice-president of the AMA in 1939. He has also been Executive Secretary of the Highway Education Board and Washington representative of the AMA. In 1923, Mr. Johnson represented the automobile industry at the First International Road Congress at Seville, Spain. He was United States delegate to this body at Milan, Italy in 1926 and at Washington in 1930. He was Executive Secretary of the first and the second Pan-American Highway Congresses—at Buenos Aires in 1925 and at Rio de Janeiro in 1929—and Executive Director of the Pan-American Confederation on Highway Education. He was decorated with the Legion of Honor by the French Government in 1933.

THE traffic problem in any city involves many uncertainties and unknown facts. One thing is sure however—the traffic problem is not getting easier to whip. More and more people are living in cities and environs, and traffic is increasing more than proportionately.

Viewed dispassionately, the things wrong with cities may cause wonder as to why so many people prefer to live in them. But smoke and smog, dirt and noise, crowded transit vehicles, traffic congestion and delay, are annoyances that fall short of nullifying conveniences and attractions of city living. Yet city people want to endure these nuisances and conflicts no longer than necessary. The daily press and programs of civic and service groups point out the constant effort directed to making city life safer and more comfortable.

More and more people are turning to the metropolis. In 1790, when town and rural life were full of tribulation, only five per cent of the people lived in urban centers. As educational, cultural and vocational facilities improved, the steady drift to cities began. Today

fully 60 per cent of our population lives in cities, a total of 90 million.

Although there are 3,464 cities of 2,500 or more population, far more people live within the 199 cities having populations of 50,000 or over. Often cities and towns are clustered together, forming large metropolitan districts. Areas most favorably endowed with natural resources, geography and climate are the logical targets of man's gregariousness. So it is not surprising to find that 200 counties, about six per cent of all counties, contain more than half of all people in the United States.

Much of the growth of American cities occurred during the half century of the motor vehicle, but little was done to adjust city development to the abilities and needs of this modern means of transportation. Meanwhile, the economy of the nation became dependent upon the motor vehicle. The same streets and the same kind of streets that saw the birth of the automobile carry today's sleek passenger cars, roomy buses, and powerful trucks. In many cases, the methods of administering and controlling traffic are equally antiquated.

Why is a matter for conjecture. During the last fifty years two major depressions and two major wars occurred. It was not clear until World War I that the motor vehicle was going to become increasingly useful and popular. Again, in 1940 it was not known that truck usage would be almost doubled and the total motor vehicle registration 50 per cent greater in just eight years.

Sheer size of the traffic problem is sufficient to frighten or discourage many a citizen. Recent proposals to eliminate use of passenger cars in downtown areas would never be countenanced by a car-loving people who have already shown their independence by shunning poor traffic facilities to patronize easy-to-reach shopping areas with adequate parking accommodations.

Another reason for delay in tackling traffic problems is fear of cost. That often comes from inadequate knowledge of the problem's scope and character. Finally, many cities fail to give proper responsibility and authority to the traffic-operations arm of their government.

Whatever the reasons, the fact remains that practically every American city suffers heavy loss through traffic congestion and delay

and traffic accidents. Much of the loss is needless and could be avoided at costs far less than the benefits. That can be said with certainty because modern traffic management and operation techniques have proved it.

The traffic problem can never be met by a quick trip around town, discussion with a few city officials and businessmen, and a visit to the warehouse to pick up a few traffic signals and a bucket of paint. There was a time perhaps when that sort of procedure was enough. But today the traffic problem is complicated. It is not one problem but several inter-related problems. The major divisions are traffic congestion and delay, traffic accidents, and parking. Solving each of those brings to light other problems, including traffic administration and control, engineering and construction of physical improvements, truck and mass transit operations, traffic ordinances, education and enforcement.

Clearly, the urban traffic problem has grown too large, too intricate, and too important to be trusted to rule of thumb treatment and to management which lacks know-how and authority.

Traffic Management Needs Responsibility and Support

When traffic first became a serious problem, cities usually referred the infant headache to some employee in the police department or city engineer's office who put up warning signs and perhaps installed traffic signals at locations dictated by personal opinion or public pressures. As traffic volumes and problems increased, some cities early saw the need for establishing traffic management on a sound basis, either giving it department status or high standing in the city engineering or public works department. But in a good many cities, traffic operations and management duties are scattered among different city departments. Under such conditions, chances are excellent for a continued archaic traffic handling and needless waste.

Among several cities which recently have brought traffic management to a high level of responsibility is Los Angeles. In that city the job of controlling traffic began a quarter of a century ago when the city electrician was asked to install a few traffic signals. The city gov-

ernment didn't quite know what to do with this new activity, and so it was passed from department to department.

A traffic engineering department emerged, but traffic functions were also shared by eight other city departments or agencies. This caused inaction, delay and compromises, not always to the benefit of drivers and tax payers. Mayor Fletcher Bowron and the city council agreed about a year ago that Los Angeles could never get anywhere with her traffic problem without traffic administration.

City officials determined to make a comprehensive study which would place on the table all the facts, not only administrative conditions and needs, but the failure to obtain and apply facts. A study committee was established, with the head of the Automotive Safety Foundation's traffic engineering division serving as chairman on a basis of reimbursement for out-of-pocket expenses.

Last winter the committee report was presented. It called for consolidation of traffic engineering functions under a traffic engineering department equal in status to that of other city departments. The committee recommended a traffic engineering commission comparable in organization and authority to other city commissions. The recommendations were preceded by a complete review of Los Angeles' street traffic problems, with emphasis on the need for a variety of factual studies.

Acting promptly on the report, the city council ordered drafting of city ordinances, and within a few weeks the study committee's recommendations were written into the city laws. The plan became effective last July. This prompt action is attributable to several factors—alert city officials, intolerable traffic conditions, and a report not only attractive and easy to understand, but one which bluntly and courageously told the story.

There is nothing new in Los Angeles' modernized traffic management. Other cities—Detroit, New York, Dallas, Houston, and Syracuse—have also junked antiquated procedures. But Los Angeles deserves high credit for making a thorough study before establishing the new department. The challenge now is to the traffic engineering administrators and personnel.

The next necessary ingredient, and this applies to all cities, is support—support by public officials and support by the public itself.

Often policy-making public officials are lethargic in traffic matters, and too often the public is resistant to change. You can't blame public officials too much when the public itself fights improvements. Many a city has suffered years of delay in such simple things as one-way streets or through-street systems because of lethargy or resistance on the part of affected property and business owners. This leads to another essential—the collection of facts.

Facts Are the Fulcrum

Today decisions of consequence affecting traffic should not be made without facts—facts derived through special studies. Books give broad answers to traffic problems but traffic conditions need solutions tailor-made for each problem, and with due regard for related problems. Thomas H. MacDonald, Commissioner of Public Roads points out, "Experience is a great and important teacher, but repetitions without critical analysis of even a proven course may wear a rut so deep that other and perhaps more desirable courses are lost from view."

Several types of studies can be conducted at relatively low cost. Moreover, the door is now open for cities to share costs with state highway departments and the Federal Government through federal highway aid designated for research and engineering. Both the state and the Federal Government have a deep interest in urban traffic because of the heavily traveled extensions of the Federal aid highway system and secondary roads. Obviously state, federal and city engineering forces, with their trained personnel and the U.S. Bureau of Public Roads through its broadly experienced specialists, can produce valuable factual studies for both current and long-range application.

The Albuquerque Fact-Finding Study

A current project illustrating this cooperation is now well under way in Albuquerque, N.M., where the state and Federal Government are aiding the city in an overall study covering seven major phases of the traffic problem. With costs shared by the three government agencies, the Automotive Safety Foundation is directing the study at the request of the officials concerned. It will be completed

early next summer. There is nothing unusual about the Albuquerque individual studies; with one exception they are the same as many cities have conducted singly or in conjunction with others. The unique thing is that never before have several essential studies been conducted at the same time and in a way to produce the greatest inter-relationship in determining needs and solutions.

Albuquerque's study embraces the following:

A. A study of all streets inside the city with recommendations for using present facilities most efficiently.

B. Development of a plan for a classified system of arterial streets based upon origin and destination and other traffic and land-use studies. A master plan for street development fitted to present and future use with recommendations for geometric design. Also, integration with important regional routes to be considered.

C. A parking study to recommend curb parking controls and to improve off-street parking.

D. A study of truck routings and terminals in the area.

E. A study of mass transportation, including bus and taxicab transportation in the area.

F. A comparison of the Albuquerque traffic ordinances with the Model Traffic Ordinance.

G. A review of the administrative machinery for handling traffic and transportation in the city.

Probably most people still think of Albuquerque as the small city of 35,000 it was before the last war. Today, the chief city of New Mexico, the home of Sandia Atomic Energy Base and just about the busiest airport in the world, Kirtland Field, is a bustling city of at least 85,000 people. Another 35,000 live close to its borders. Because of her rapid and continuing growth, the present studies are considered extremely timely. Certainly the possession of facts will better enable the city to accommodate her added population and to replace the small-town methods and procedures with those fitted to the needs of a growing city.

Coverage of Albuquerque Study

A brief of the Albuquerque outline will make clear the coverage and inter-relationship of the studies:

Development and growth of Albuquerque and environs are reviewed in the opening section, largely in terms of transportation. Included are the reasons for locating the original settlement, the effect of different nationalities (Spanish, Mexican, and U.S.), relation of city to adjacent area and to the state, topography, population growth, and finally the effect of the motor vehicle.

Another introductory section deals with economic factors in terms of transportation. It traces community needs in manufacturing, retailing, recreation, touring, and with respect to the government establishments, Sandia Base and Kirtland airfield. Other investigations cover the city's importance as a distribution center, the relationship between highways and railroads, cost of congestion, accidents and inadequate parking, and an estimate of the area's future economy.

Many special and helpful studies have been pigeon-holed because too little attention had been given to reasons *why* recommendations fitted actual needs of the city. In this case, Albuquerque has grown so rapidly that many do not realize how magnified have become the problems of the small town of a decade ago. Any study would be of little value to the city unless it emphasized that through population and business growth Albuquerque has become a large city. It cannot meet responsibilities to its citizens without providing itself with expanded facilities and know-how to do the job.

A thorough study of the present-day traffic pattern includes factual determination of the amount of traffic by different types of street vehicles and pedestrians, and the variations by season, week, day and hour. Traffic volumes in relation to street width will be presented graphically. Studies of origin and destination of travel within and outside the city will determine desire lines of travel. Time studies will show time required for trips on various routes. Major traffic generators will be located and described, and traffic flows will be related to land use. All this information is fundamental to the studies that follow.

Most cities have a street plan of one kind or another. Many were laid out years ago and have been followed without regard to changing conditions. Consequently a study of wide character starts with review and possible improvement of the existing street plan.

In Albuquerque the entire street system is being studied to reveal the origin and destination of traffic, land use and traffic volume.

Determination of needs for traffic engineering and street improvement will be through a city-wide study of street capacities. This is the first time such a step has been taken.

This is done by first determining traffic demands on all streets by means of volume counts. These are then compared with the capacities shown in the Highway Capacity Manual, available after long study by O. K. Normann of the Bureau of Public Roads, who is consultant on this part of the Albuquerque study. Streets serving beyond their practical capacities will be assigned corrective traffic engineering measures. In cases where the corrective steps still do not meet traffic demands, attention will be given to major street improvements; widening, viaducts, express highways, etc. In this way we can assure the best possible use of present facilities.

The street plan study will recommend an arterial route plan within and outside the city and an improvement program including costs and priorities.

An important phase of the Albuquerque study is to make the best possible use of existing streets. Studies of existing desire lines of travel will be extremely helpful. Too often traffic operations are handled on an unplanned basis without frequent appraisal of their success, failure or changing needs of traffic. The Albuquerque study will make every effort to fit together regulatory measures, traffic routing procedures and minor physical improvements to produce the greatest good in terms of traffic flow and reduction of accidents. It will recommend not only immediate relief measures but will prepare the city for future traffic increases by projected improvements in facilities.

A good many cities are failing to make the best possible use of existing streets because of anticipated high cost. Actually many things can be done that cost no more than present inefficient methods. There is nothing expensive in routing traffic properly through turning controls, one-way street systems and through-streets.

A top problem in most cities today is better parking. One mistake in approaching this problem is the failure to appraise it. Careful study may show that the lack of adequate parking causes serious loss

of business to the downtown section. Curb space may not be used to the best advantage. Parking periods along curbs may be too long or too short. Study may prove that parking should be banned during rush hours or for all day on busy streets.

In Albuquerque, business people feel that too many tourist dollars entering the city go on to more distant points. Consequently the parking study will investigate every aspect of the parking problem. Two surveys were conducted—one inspecting all parking facilities, both curb and off-street, and one interviewing over a month's period virtually all parkers in the downtown area. When the facts are analyzed, both location and quantity of the parking demand will be known.

Of growing importance in all cities is the problem of truck routes and terminals. Cities are affected by the congestion at various points because of truck movement or of trucks loading and unloading at retail stores and industrial plants. Consequently, the Albuquerque study will penetrate the problem to determine recommendations for control of loading and unloading, for marking truck routes, and for establishing or improving terminals.

A companion problem to the hauling of merchandise is the hauling of passengers. As present day systems with their multiplicity of street intersections handicap the movement of passenger cars so do they handicap the use of mass transit vehicles which must provide the best possible service in order to appeal to the public.

If all persons were to abandon mass transit and use their private cars, the present street systems could not accommodate them. Consequently in attempting to improve traffic conditions within a city, every practical step must be taken to make mass transit efficient and safe so that transit may remain healthy and keep pace with city growth. Studies will be made of the origin and destination of transit riders, and of routes and schedules. Attention will be given to special controls for transit vehicles particularly with respect to loading zones.

Taxicabs might appear a matter of small moment in a general traffic study. However, even though taxicabs are comparatively few, extensive, often urgent, use is made of them. Of particular importance is the establishment and control of taxicab stands. In Albuquer-

que a rather odd situation exists. There, taxicabs are not permitted to cruise but must answer all calls from central locations. Speed and delay studies will be made of taxicab operations and recommendations will be based on steps to increase the efficiency of this vital means of transportation.

The Albuquerque study gives careful attention to present duties and functions of the present city departments in traffic matters. Essential traffic management functions will be determined and recommendations will be made for centralizing traffic management authority and for establishing proper relationship between engineering and enforcement functions.

One other problem that many cities face of prime importance in improving traffic conditions is adoption of sound traffic laws and ordinances. Not only should laws and ordinances be sound but they should conform with the Model Traffic Ordinance. No city can expect to approach perfection in traffic handling or enforcement unless it adopts uniform vehicle laws. In Albuquerque there is a tremendous flow of tourist travel from all parts of the country.

Cities that neglect to conform with the Model Traffic Ordinance are actually inviting guests to meet death, accidents and delay. Consequently, Albuquerque study recommendations will be made keeping in mind the relationship of the city ordinances to the state motor vehicle code and to the Model Traffic Ordinance.

The concluding section of the Albuquerque study will concern itself with the all-important problem of traffic safety. Traffic safety is the sum total of all things done to cause traffic to flow harmoniously and with reasonable speed. However, there is a tendency among cities to think of traffic safety as something that is largely a problem of enforcement and education. Many cities, for example, fail to analyze properly accident records to strengthen weak spots in the city-wide safety program so that hazardous accident locations can be recognized and given the engineering, enforcement and educational treatment needed. In the Albuquerque study an inventory will be made of all safety activities within the city in conformance with the National Traffic Safety Contest. Recommendations of the President's Highway Safety Conference will form the basis of the elements of the coordinated safety program.

The Albuquerque study is actually a factual diagnosis of seven major inter-related traffic problems, with the work so conducted that each portion of the study provides information essential to other phases. No professional man or scientist can tackle a problem successfully unless the facts are brought to light. When facts are properly presented, problems clearly seen, and solutions spelled out, the chances of success are infinitely greater.

The Designing of Intersection Channelization

FRED W. HURD

Mr. Hurd is an Associate in Research with the rank of Associate Professor at the Yale Bureau of Highway Traffic. Previously he had been a highway designer and project engineer for the Missouri State Highway Department for ten years, a traffic engineer for the Missouri State Highway Department for two years, a traffic engineer for the Michigan State Safety Commission for one year and a traffic engineer for the Michigan State Highway Department in the Planning and Traffic division for three years.

INTERSECTIONS cause many of the critical problems in highway traffic operations and control. Where the intersection is *at grade,* streams of turning and crossing vehicles must join and cross each other. The points within the intersectional area used in common by intersecting streams are focal points of accidents and delay. Delays result when vehicles in different streams wish to pass through these focal points at the *same time.* Accidents result when drivers make mistakes in judgment of the *time* and *place* that intersecting movements will occur.

The *time* and *place* of conflicts at intersections may be altered by traffic controls or design. Traffic signals separate intersecting traffic streams by allotting different *times* for vehicles to use the intersection. Grade separations eliminate the *place* of conflict by bridging one stream over the other.

Channelization is the establishment of traffic channels within, and upon the approaches of, intersections to control the *speed* and *path* of vehicles. Through channelization, the *place* of conflict between intersecting traffic streams may be controlled and the *time* element may be influenced by the separation of conflict points and control of the angle and speed at which conflicts occur. Therefore, channelization promotes safe and orderly intersecting traffic movements where more expensive or restrictive measures are not justified.

This channeling applies to all types of intersections. It enjoys its fullest application in suburban areas where speeds are moderate and the larger space required by channelization may be obtained at reasonable cost. In urban areas, this additional space is frequently too expensive to acquire. In rural areas, high speeds call for generous dimensions that may be prohibitive with the result that only partial or limited channelization is practical.

The design principles of channelization are flexible in application. Use of all, or a few, of the principles depends upon the physical and traffic factors encountered at individual intersections. The purpose here is to define and discuss these principles. Their application depends upon the problems presented by particular intersections and is therefore the responsibility of the design engineer.

1. Merging Intersection Movements Are Most Desirable

At intersections, vehicle streams may cross or merge. Merging takes place when two traffic streams unite to form a single stream. If merging can be effected at an angle of less than 10 degrees between the joining streams, both streams may be allowed to enter the intersection without stopping. This permits a gradual convergence of streams with all vehicles moving at about the same speed. Since the speed differential, as well as the angle of convergence, is small, drivers have more time to avoid collisions by slight adjustments in speed and path.

A merging movement permitted without stopping either stream will increase the capacity of an intersection. Studies of intersection performance* have shown that when one stream is allowed to merge with another without stopping, the average driver will enter a three second time gap between vehicles. On the other hand, the average driver required a six second gap in traffic to enter or cross a moving traffic stream from a stopped position.

Accidents should be less severe in merging traffic. When vehicles moving in the same direction at nearly the same speed collide, the impact is a function of the difference in speeds. For example, the

* Wynn, F. H., Gourlay, S.M., and Strickland, R.I., *Studies of Weaving and Merging Traffic*, A Symposium, Technical Report No. 4, Bureau of Highway Traffic, Yale University, 1948.

speed of collision when a vehicle traveling at 50 mph runs into the rear of one traveling 40 mph is 10 mph.

Traffic streams may make *direct* or *indirect* crossings. *Indirect* crossings occur when one traffic stream weaves through another. A weaving vehicle may merge into a through traffic stream on one side, filter across one or several lanes and diverge from the stream on the other side. Or, as in the case of a traffic circle, the weaving vehicle may merge and diverge on the same side of the through stream. Diverging is the gradual departure of one stream from the other and, as such, does not present an intersection problem when turns are made from the proper lanes.

At direct crossings, traffic streams cross at a single point without mergence, at angles ranging from merging to head-on. It is generally necessary to stop the minor stream at the approaches to a direct crossing because the angle of crossing is conducive to serious accidents. Therefore, direct crossings have lower capacities and higher accident potentials than indirect crossings. Unfortunately the cost of construction of such facilities as merging lanes, weaving chambers and traffic circles which are required to effect indirect crossings is not justified at most intersections.

2. Direct Crossings Should Be Made at Right Angles

At the usual intersection, the designer has no choice but to allow the direct crossing of traffic streams at grade. Most roads accommodate two way traffic. Merging angles for some streams of cross traffic usually result in angles approaching head-on for the opposite direction flows.

Head-on angles of conflict cause mistakes in driver judgment and also cause increased accident severity. Good speed judgment, as drivers approach a crossing, enables both drivers to anticipate the time when they will reach the point of intersection and permits them to avoid arrival at the point of conflict at the same time. Drivers employ two visual clues in speed judgment. One is the apparent rate of increase in the size of the approaching vehicle and the other is the rate at which it flashes past fixed objects along the road side.

The only visual clue applicable to the head-on approach is the

apparent increase in the size of the approaching vehicle. In the event of a head-on collision, the speed of impact is a resultant of the sum of the speeds of the two vehicles. For example, a head-on collision between vehicles, each traveling at 50 mph, would result in an impact speed of 100 mph.

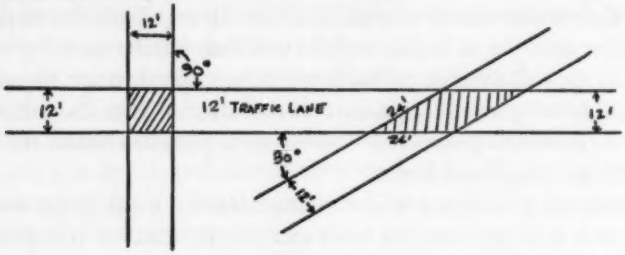


FIGURE 1

Drivers are more accustomed to right angle crossings. Most intersections cross at approximately 90 degrees and drivers are more experienced in judging speed and timing at this angle of approach.

Right angle crossings reduce the area of intersection. When traffic lanes cross at 90 degrees, the area which is common to both lanes is smaller than when the crossing is skewed. Accordingly, the time of crossing is reduced with decreased blockage and accident exposure. Figure No. 1 compares the geometry of a skewed and right-angle crossing.

3. Vehicle Speeds May Be Controlled by Bending or Funneling

Vehicles describing a curved path are acted upon by centrifugal force. When the centrifugal force is not offset by the banking of the road, it is felt by the occupants of the vehicle as side thrust. Excessive side thrust is uncomfortable and becomes alarming when it is strong enough to approach side skid proportions. Centrifugal force increases with increased speed and sharpness of turn. Therefore, by reducing the radius of turn, drivers may be forced to reduce speed.

Reduction of the speed of traffic by reducing the radius of turn is called *bending*. Figure 2 shows two examples of reducing speed at intersections by bending (a) by an island in the intersectional area and (b) by bending the side road approach.

It should be acknowledged that bending traffic streams may cause increased hazard. The change in direction may be accomplished by a series of compounded curves or a spiral curve calling for a gradual reduction in speed.

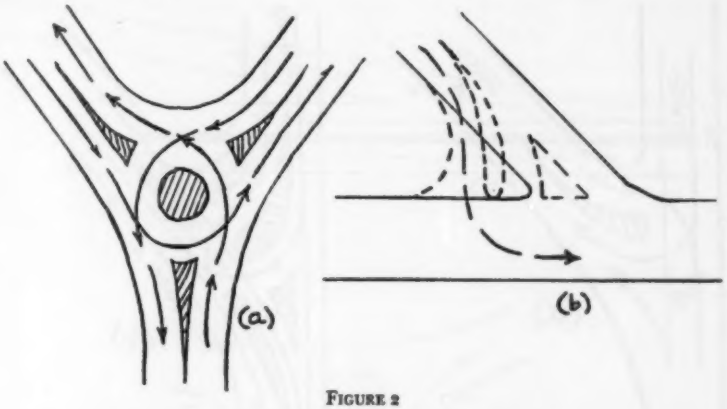


FIGURE 2

Funneling is the gradual narrowing of traffic channels to the extent that drivers reduce speed because of the psychological effect of the width restriction. Funneling of single traffic lanes, only, is practical. It cannot be used where two lanes of traffic would be bottlenecked into one lane. The theory of funneling is limited in application.

4. Heavy Traffic Volumes Should Be Given Preference Over Minor Streams

In the design of channelization, major traffic streams through the intersection should be given preferential treatment. The "authority" of through traffic should be clearly indicated by the speed and angle of approach.

Minor traffic streams should be bent the most. Major streams should be permitted to proceed through the intersection along a better alignment and therefore at a higher speed. Figure 3 shows examples of preferential treatment of through traffic. In Example (A) the speed of traffic on road A is reduced by bending. This *subjects*

the minor traffic on road A to the through traffic on road B both physically and psychologically to cause the side road driver to give way to through traffic. Example (B) shows treatment of an intersection of the same shape where road A carries the major flow.

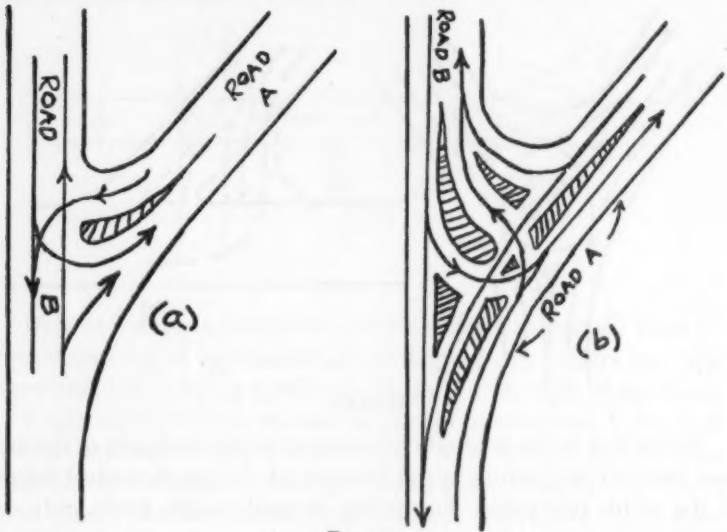


FIGURE 3

5. Merging Traffic Should Enter Through Stream on Right Side

In Figure 4, traffic may enter the through stream on approach A with greater safety than on approach B. A driver's vision is better out of the left side of his vehicle than out of the right side where his

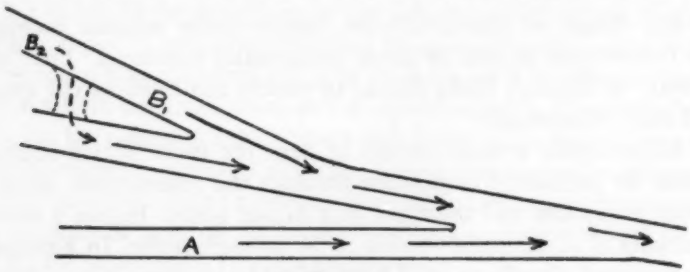


FIGURE 4

view may be blocked by passengers, fogged windows or the metal corners of the cab. In numerous cases, drivers have indicated a preference for approach B_2 as compared with B_1 by driving off the paved portion of the road as indicated by the dotted line.

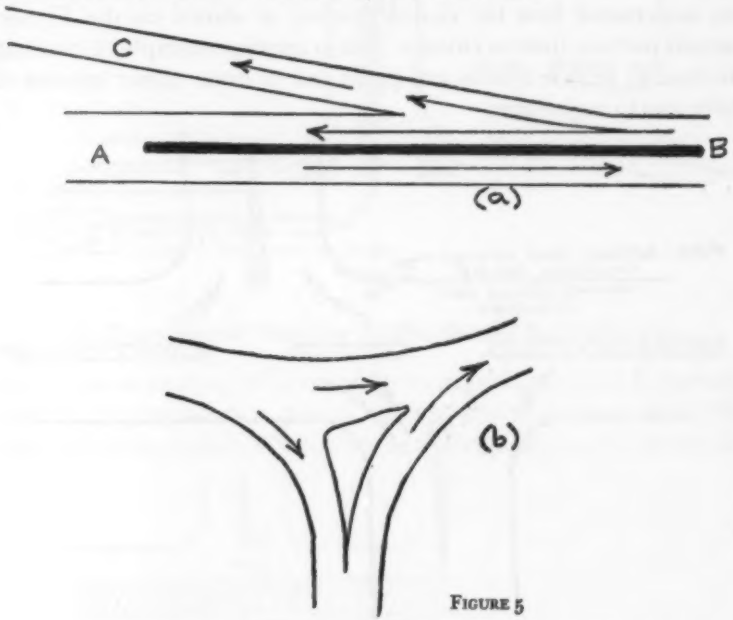


FIGURE 5

6. Channelization May Be Used to Discourage Prohibited Turns

Figure 5 shows examples of the application of channelization to block prohibited turns or to make the execution of such turns very inconvenient. Example (A) shows an island blocking the left turn from road A to road C. This treatment is frequently used at the entrance of ramps at grade separations. Example (B) shows the design of an entrance to a traffic circle devised to prevent left turns.

7. Left Turns Should Be Controlled

It is a natural tendency for drivers to choose the shortest path. At intersections where left turns are not controlled by channelization,

some drivers will shorten their path by excessive "cutting of corners." This places the turning vehicle on the wrong side of the road for other vehicles and for pedestrians. The arrows on Figure 6 represent typical accidents caused by improper left turns. It is not difficult to understand how the channelization, as shown on the Figure, would prevent these accidents. This is another example of bending to control vehicle speeds and paths and to cause minor streams to give way to major ones.

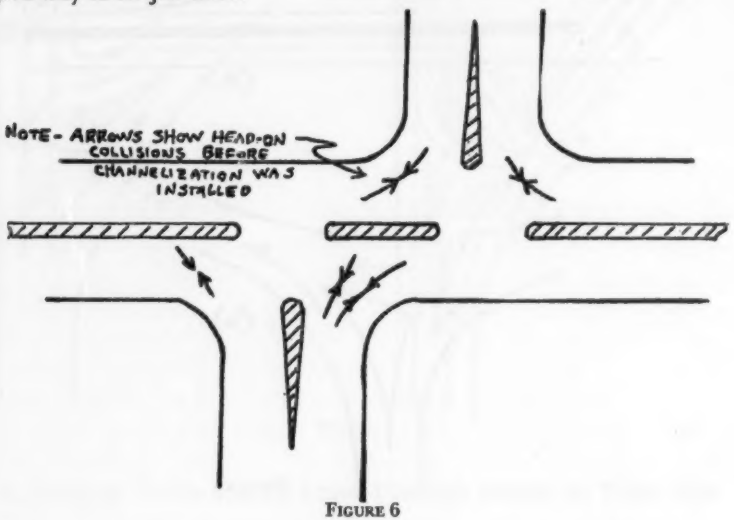


FIGURE 6

8. Acceleration and Deceleration Lanes for Turning Traffic

The speeds of left and right turns at intersections are usually lower than the speed adopted by through traffic. Smoothness of flow is interrupted when turning vehicles decelerate while they are a part of the through traffic stream. Deceleration lanes permitting turning traffic to decelerate on a separate lane after leaving the through stream will prevent this interference.

Acceleration lanes for vehicles completing a right or left turn permit smooth merging into the through stream with the advantages previously discussed. Figure 7 shows examples of acceleration and deceleration lanes at grade intersections.

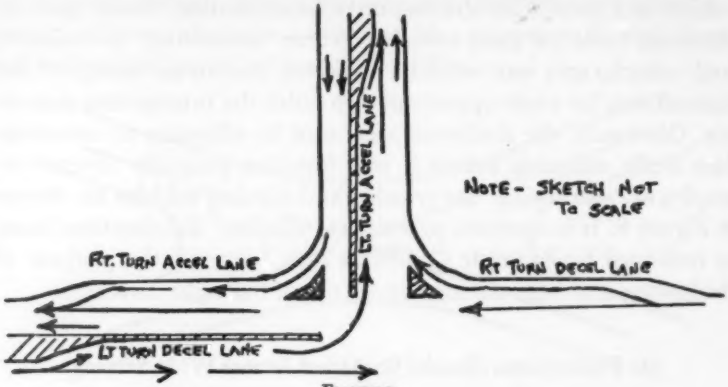


FIGURE 7

9. Crossing and Turning Traffic Should Be Shadowed

At busy intersections, left turn and crossing vehicles must frequently wait in the intersection for an opportunity to cross or enter the through traffic stream. While waiting to complete the maneuver, the

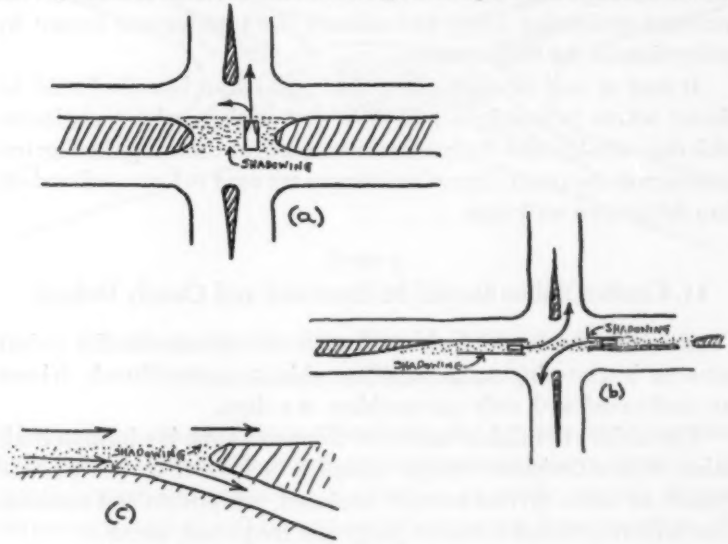


FIGURE 8

vehicle is a hazardous obstruction. Channelization should provide sheltered areas for these vehicles. When "shadowing" is available, such vehicles may wait within a protected zone in the middle of the intersection for a safe opportunity to finish the intersection maneuver. Obviously, the shadowed area must be adequate to accommodate traffic demands before it will function properly. Several examples of "shadowing" for crossing and turning vehicles are shown as Figure 8. It is common practice to "shadow" deceleration lanes, as indicated by Example C. In this case, however, the purpose of shadowing is to keep through traffic out of the right turn lane.

10. Pedestrians Should Be Aided Across Wide Streets

Channelizing islands in the center of intersection approaches as well as the islands adjacent to right turn lanes are useful as an aid to pedestrians crossing wide streets. They provide zones of refuge where a pedestrian may wait in safety when caught in the street by traffic. Where pedestrian safety zones are provided, pedestrians need to cross through only one direction or stream of traffic at a time. This increases pedestrian safety and reduces the interference caused by pedestrians in the traffic stream.

It may as well be stated here that pedestrian islands should be placed where pedestrians will cross rather than where engineers wish they would cross. Pedestrians are noted for choosing the shortest paths across the street. Sometimes fences are used to force pedestrians into designated walkways.

11. Conflict Points Should Be Separated and Clearly Defined

Traffic channels should be located so as to separate conflict points between intersecting streams. When this is accomplished, drivers are confronted with only one problem at a time.

The ability to think of only one thing at a time is a human limitation. When decisions become complex or involve more than one stimuli, or when drivers become confused, perception and reaction time is increased and errors in judgment frequently occur.

In Figure 9, the driver of the vehicle shown by the solid line must

watch simultaneously for conflicts with vehicles from every other approach; whereas, after channelization, his path passes through four well defined and separated points of conflict.

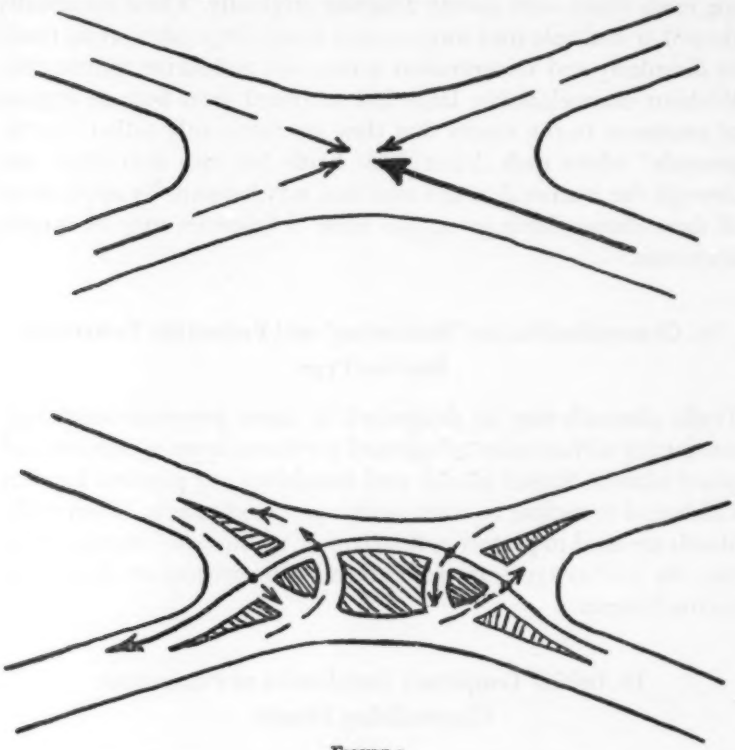


FIGURE 9

12. Channelization May Provide Locations for the Installation of Traffic Controls

Islands in or near the intersectional area also provide ideal locations for signs and signals. Their unique position near points of conflict in the intersection permits the installation of traffic control devices where such devices will be seen by drivers at the location where observance is expected.

13. Excess Paved Area in Large Intersections Should Be Eliminated

Channelizing islands may be introduced at the intersection of existing roads which were poorly designed originally. These are usually skewed or multiple road intersections where large paved areas result in disorderly and uncontrolled driver and pedestrian movements. Without channelization, large intersectional areas become regions of confusion to the extent that they are frequently called "battlegrounds" where each driver must battle his own individual way through the intersection and anything may happen. By application of these channelizing principles these deficiencies may be largely overcome.

14. Channelization for "Shadowing" and Pedestrian Protection: Barrier Type

Traffic channels may be designated by signs, pavement markings, contrasting surface color, roughened pavement areas, stanchions and raised islands. Raised islands and stanchions are physical barriers which tend to confine vehicles to their proper channels. When traffic islands are used to protect pedestrians or to "shadow" turning vehicles, the barrier types are recommended to prevent or discourage encroachments.

15. Initial Temporary Installation of Permanent Channelizing Islands

The best channelization designs on the drawing board may develop imperfections when placed in effect on the street. Permanent construction such as curbs, raised islands, etc., cannot be easily changed and therefore should not be attempted until after the channelization scheme has been tested by traffic. For this reason, channelization should, at first, be placed in effect with temporary islands. Portable stanchions, wooden platforms, bags of sand and other movable objects may be used to construct islands which may be changed in shape and location as dictated by traffic demands. Surface paint markings are not as desirable for this purpose. Drivers may cross over paint

Courtesy City of New Haven Traffic Commission

FIGURE 10. Photo of Temporary Channelization

lines rather than follow prescribed paths requiring them to reduce speed or suffer even slight inconveniences. Figure 10 shows temporary channelizing islands formed by sandbags.

Conclusion

Contrary to some belief, channelization will not reduce the capacity of an intersection. If the islands are properly shaped and located, they occupy space not needed by traffic. Because they are an obstruction in the roadway, raised islands may be shunned as a traffic hazard. Where the design is in keeping with the speed, volume and other traffic requirements, and adequate warning and illumination are used, accidents caused by running into the islands are negligible.

By simplification of intersection movements, channelization utilizes the natural skill and ability of drivers to the fullest extent. The resulting elimination of confusion and the more efficient use of the intersectional area decreases congestion and accidents.

It may therefore be said that the greatest improvement resulting from intersection channelization is the creation of orderly flow. Orderly flow through channelization should be self-enforcing when proper channels are obvious and improper maneuvers are made inconvenient and unnatural to perform.

Evaluating Highway Improvements on Mileage-and-Time-Cost Basis

LAWRENCE LAWTON

Lawrence Lawton was recently appointed Assistant Civil Engineer (highway traffic) with the newly formed Department of Traffic Engineering, City of New York. He is head of the Traffic Signal section, working under the direction of John T. Gibala, Engineer of Traffic Control. Until his recent change, Mr. Lawton was working under Fred Fisch, Director, Bureau of Arterial Route Planning, New York State Department of Public Works. Prior to this, he was engaged in expressway design in a consulting engineer's office.

URBAN areas today are experiencing the stagnating effects of traffic congestion. Many palliatives, refining details in existing street systems, have been used to remedy the situation. Experience has shown these measures unable to cope with the mounting tides of traffic.

The construction of new arterial facilities is the only permanent remedy. The highest type is the expressway that may cost between one and five million dollars a mile. Next is the limited access highway with grade separation at important intersections costing between half a million to a million dollars a mile. The simplest arterial facility takes the form of street widening and repaving and may cost between two and six hundred thousand dollars a mile.

A need has therefore arisen to determine the economic justification of these proposed facilities. It is necessary to compare the merits of existing highway with the merits of proposed alternate routes. The economic savings accrued by a new facility must be estimated. Then the costs of both existing and proposed facilities, using a proper method of amortization, should be determined. These costs would include needed items, new pavements, auxiliary structures and maintenance.

Please insert at page 102 of the January 1950 TRAFFIC QUARTERLY, "Evaluating Highway Improvements on Mileage-and-Time-Cost Basis, by Lawrence Lawton.

MAY 5, 1950

The Editor, TRAFFIC QUARTERLY
Eno Foundation
Saugatuck, Conn.

Dear Sir:

It has come to my attention since publication of the January issue of the TRAFFIC QUARTERLY that there are some errors in my article appearing at page 102. I feel that correction of these errors should be brought to the attention of the readers. They are as follows:

Page 105:

(line 9): t = toll cost on improved facility
Should read: T = toll cost on improved facility

(line 13): $n = \frac{S_1 - S_2}{2}$ (use algebraic sum)

Should read: $n = \frac{S_2 - S_1}{4}$

(line 15): Then $x = \frac{T-4cn}{d(k-1 + 2n(k+1)} \times \frac{V_1}{60}$

Should read: Then $x = \frac{T-4cn}{d(k-1) + 2n(k+1)} \times \frac{V_1}{60}$

Page 106, lines 3-10 should read:

The distance by the Boston Post Road is seventy miles and by Merritt Parkway is seventy-eight miles. The average speed by Boston Post Road is twenty-two miles an hour and by the Parkway is forty miles an hour. In 1940 the toll charged was forty cents.

$$x = \frac{40-(4)\ (3)\ (-2)}{74(1.82-1) + 2(-2)(1.82 + 1)} \times \frac{40}{60} = 0.865 \text{ cents per minute}$$

$60 \times 0.865 = 52.0$ cents an hour

Page 113: $\text{cost} = \frac{15 \times 65{,}000}{100{,}000{,}000} \times \frac{1}{100}$

Should read: $\text{cost} = \frac{15 \times 65{,}000}{100{,}000{,}000} \times 100$

Sincerely yours

LAWRENCE W. LAWTON (Signed)

Automobile Operating (Mileage) Costs

Passenger vehicle costs may be broken down into two groupings: fixed costs and mileage costs. Fixed costs are independent of the number of miles a car is run. They are composed of such items as depreciation (due to age of vehicle) registration and license fees, insurance, garage rent, and maintenance (independent of mileage). Mileage costs on the other hand vary directly with the distance traveled. Gasoline, oil, tires, and depreciation (that part due to miles traveled), fall in this category.

Fixed costs will remain the same whether a car is run ten miles or ten thousand miles a year. For an economic comparison of two highways, therefore, only the direct mileage costs need be considered.

One of the first authoritative studies was made by Robely Winfrey of Iowa State College in 1931. He arrived at a value of 3.85 cents a mile. An excellent estimate was made by the Oregon Planning Study of 1938. They determined the mileage cost to be 3.21 cents a vehicle mile. Tabulated calculations of these studies are presented in Tables 1 and 2 of the appendix.

These estimates are obsolete because of the rise in the general price level from 1939 to the present time. Therefore the estimate of 1948 cost a vehicle mile is presented below.

ESTIMATE OF 1948 COSTS

	Annual Cost	*Cost Per Mile Cents*	*Direct Mileage Costs*
Gasoline, 23 cents a gallon		1.53	1.53
Oil, 35 cents a quart		0.21	0.21
Tires, $19 for Tire & Tube		0.25	0.25
[1]Depreciation, Car Costs $2200	$250.00	2.50 x 1/3 =	0.83
License & Registration	18.00	0.18	
Insurance	90.00	0.90	
Garage	48.00	0.48	
Maintenance	100.00	1.00 x 2/3 =	0.67
		Σ = 7.05 cents a mile	Σ = 3.49

[1] See Appendix V.

Assumptions

1. Oil change, 6 quarts, every 1,000 miles.
2. Average gasoline consumption, 15 miles a gallon.
3. Change tires every 30,000 miles.
4. Average vehicle, travels 10,000 miles a year.
5. Depreciation costs calculated as a straight line function, with average life of eight years and 10% residual as salvage value.

The total cost per mile is 7.05 cents of which 3.49 cents is the direct mileage cost. This estimate *compares favorably with the total operating figure of* 6.8 cents a mile calculated by The New York Telephone Company. It would be expected that their costs would be slightly lower because of efficient fleet operation.[1]

Value of Passenger-Vehicle Operator's Time

Earliest estimates of a motorist's time value was based on his hourly earning capacity. It seems reasonable as it is the value placed by the economy upon the individual's time. The figure commonly used is the average wage of factory labor. In New York State at the present time that rate is $1.25 an hour. Since the driver actually receives no monetary compensation for leisure time, this reasoning is questionable.

Time-saving can be determined by the price motorists pay on a toll facility. A new facility results in its use by many people who previously declined to use the highways available. This stimulation is termed induced traffic. Since this *induced* traffic has the choice of using the existing or newly opened improved routes, the toll paid divided by the time saved is the driver's actual valuation of his own time. Tabulated below is a summary of values of time-savings of facilities that have induced traffic.[2]

[1] In a later section of this report the effect of urban travel on gasoline consumption is determined. Subtracting the gasoline cost a mile gives (3.49–1.53) 1.96 as the mileage cost not including gasoline.

[2] Prepared by M. H. West for the 1946 Proceedings of the Institute of Traffic Engineers.

Facility	*Percentage of Induced Traffic During First Year*	*Time Savings to Induced Traffic*	*Price Paid Per Minute Saved to Induced Traffic*
San Francisco-Oakland Bay Bridge (Calif.)	64%	26 Min.	2.5 cents
Golden Gate Bridge (Calif.)	182	24	3.1
Blue Water International Bridge (Michigan)	27	17	3.5
Geo. Washington Bridge (N.Y.–N.J.)	49	12	4.5
Goethals Bridge (N.Y.–N.J.)	48	12	4.5
Outer Bridge Crossing (N.Y.–N.J.)	66	14	3.9
Bayonne Bridge (N.Y.–N.J.)	24	12	4.5

Average = 3.8 cents a minute
= 3.8 x 60 = $2.28 an hour

The average value of time saved is $2.28 an hour.

In "Toll Bridge Influence on Highway Traffic Operation" Earl Campbell has developed a mathematical analysis of time costs. The following formula considers time and distances on alternate routes together with vehicle operating costs.

x = Time cost per minute
c = Average vehicle operating cost per mile
$k = \frac{\text{Speed on improved facility}}{\text{Speed on existing facility}}$
t = Toll cost on improved facility
v_1 = Speed on improved facility
s_1 = Distance on improved facility
s_2 = Distance on unimproved facility
$n = \frac{s_1 - s_2}{2}$ (Use algebraic sum)
$d = \frac{s_1 + s_2}{2}$

Then $x = \frac{T - 4cn}{d\,(k-1 + 2n\,(k+1)} \times \frac{v_1}{60}$

This equation will now be applied to the Merritt Parkway and the Boston Post Road. These highways are parallel routes between New York City and New Haven. The distance by the Boston Post Road is seventy-four miles, and by Merritt Parkway is seventy-eight miles. The average speed by Boston Post Road is twenty-two miles an hour and by the Parkway is forty miles an hour. In 1940 the toll charged was 40 cents.

$$x = \frac{40 - 4 \times 3\,(-2)}{74\,(1.82 - 1 + 2(-2)\,(1.82 + 1)} \cdot \frac{40}{60}$$

$$x = 0.865 \text{ cents per minute} = 60 \times 0.865$$

$$= 52.0 \text{ cents an hour}$$

Since this value is based on a prewar figure it is necessary to bring it up to date. It is reasonable to assume that a driver's evaluation of his leisure time will be directly proportional to his income. A present day figure can therefore be obtained by multiplying the ratio of 1947 New York State per capita income by the 1940 New York State per capita income.

$$\text{Time value an hour} = .520 \times \frac{1843}{863} = \$1.11 \text{ an hour}$$

The $2.28 an hour average time value determined by the bridge tolls and the $1.11 an hour derived from the Merritt Parkway data are amounts motorists have paid for their time. There is no way of determining how much more they would have paid. In any event it does establish a tentative floor to the time cost rate.

In the case of the toll bridge, it might be argued that drivers would be willing to pay at a rate of $2.28 an hour for a short trip only. Since this figure is considerably above the average wage-rate there seems some substantiation of this. Therefore to insure a conservative figure, a value of $1.10 an hour will be adopted as the measure of a passenger-vehicle operator's time.

Time and Mileage Costs of Truck Operation

The operating cost a truck-mile consists of expenses that vary with the mileage traveled: gasoline, oil, servicing, repairs, maintenance,

tires, tubes and depreciation of shop equipment. Fixed time-costs such as depreciation, truck insurance, taxes, licenses, and general overhead, are independent of mileage.

The fixed time-costs apply to the vehicle regardless of whether or not the vehicle is in motion. Therefore the greater the use factor the smaller is the time cost an hour. The truck driver's wages, while still a time cost, vary in a direct proportion to the hours worked. For use in this study, wages are combined with the fixed time costs. The total time cost is constant for a given period of operating time so that the time cost a vehicle mile will vary inversely with the speed of vehicle travel.

There are three divisions of costs in common-carrier operation. First is local cartage which includes expenses of vehicles employed in picking up and delivering freight within terminal areas. The second category includes the expenses of vehicles that carry the consolidated shipments from one terminal to another between cities and towns. Finally there are the administration and terminal costs that must be proportionally allocated between the line haul and local cartage expenses.

It would seem at first glance that the economic savings to the two different forms of haulage resulting from the use of an arterial highway would be different. A local cartage truck spends about 45 per cent of its total time out of the terminal in loading and unloading. This is shown by the study conducted by the Board of Investigation and Research. The line-haul vehicle on the other hand occupies practically all of its operating time in running between terminals.

The best way to find the relative economic savings is to evaluate time costs from the point of view of the truck owner. Since the truck must be accompanied by a driver the time out of the terminal is limited to about eleven hours. The eleven hours is an average figure for all trucks and includes those trucks which operate sixteen hours in a day by using two drivers. Therefore the fixed time cost is divided by eleven hours to get the fixed time cost an hour. Once the truck is out of the terminal the total cost to the truck owner consists of the fixed hourly time cost, the driver's wages, and the mileage cost directly proportional to the miles run. Therefore, if in using a given stretch of expressway, ten minutes is cut from the travel time (i.e.

time cost), the saving is the same to both line haul or pick up and delivery vehicles.

A comprehensive analysis of motor truck costs was made in 1940 by the Board of Investigation and Research. This study was based on an extensive field investigation of the operation of regular route common carriers in the lower Mississippi River Valley. It was found that most carriers were unable to supply complete data since the system of record keeping prescribed by the Interstate Commerce Commission does not include the details necessary to cost finding. The field investigators of the Board were careful to segregate line haul and local delivery expenses. Presented below is a summary of the results of the survey.

Average speed	23.81 m.p.h.
Average length on haul	258 miles
Average weight carried (round trip)	4.92 tons
Average running time in hours	10.84
Mileage cost	3.95 cents per mile
Fixed hourly costs (not including driver)	$1.035 per hour
Fixed time costs per mile	4.35 cents/mi.
Wages	55.5 cents per hr. per mile
Wages, per mile	2.33 cents per mile
Total mileage costs of intercity trucking	10.63 cents per truck mile
Total costs including local delivery	20.84 cents per truck mile

The most recent authoritative survey of trucking costs in the northeastern part of the country is found in the 1945 report of the Interstate Commerce Commission. It is essentially a collation of data reported by Fleet Operators to the Interstate Commission Commerce. Although the ultimate purpose of this information is to regulate the rates charged by shippers, the data gathered is quite accurate due to the rigid field checks conducted by the commission. As was previously mentioned there is no breakdown into time and mileage costs.

Employees

Intercity Transportation	
Drivers and annual pay	4437 @ $2750
Helpers and annual pay	203 @ $1906

Terminal pick-up and delivery

Drivers and annual pay	3604 @ $2549
Helpers and annual pay	519 @ $1751

Vehicle miles operated in Intercity revenue service (with load and empty)

Trucks	18,148,444
Tractors	147,725,867

Gross costs given in the 1945 Middle Atlantic Interstate Commerce Commission data will now be computed in terms of mileage and time costs by using the breakdown of the 1940 lower Mississippi Valley study.

Ratio of gross vehicle mile costs

$$= \frac{\text{Middle At. 1945, gross}}{\text{Miss. Valley 1940, gross}}$$

$$= \frac{\$0.481}{\$0.208} = 2.31$$

Multiply Miss. Valley time and mileage costs by 2.31 to get Middle Atlantic 1945 costs.

$3.95 \times 2.31 = 9.54$ mile cents per vehicle

$\$1.035 \times 2.31 = \$2.39$ cents per hour (not including driver)

Using data supplied by the New York State Telephone Company on the total mileage costs of its fleet of 2½ ton supply trucks, 1947 truck costs can be evaluated.

Ratio of gross vehicle mile costs, N. Y. T. Co.

$$= \frac{\text{1947 cost}}{\text{1945 cost}}$$

$$= \frac{11.4 \text{ cents}}{8.7 \text{ cents}} = 1.31$$

Multiplying 1945 Middle Atlantic Costs by 1.31 to get *1947 costs*

$9.54 \times 1.13 =$ *12.5 cents per vehicle mile (including gasoline)*

$2.39 \times 1.31 = \$3.12$ per hour, fixed time cost (not including driver)

Subtracting out the gasoline cost per mile (this is calculated in the next section of this report)

$$12.5 - 5.1 = 7.4 \text{ cents per vehicle mile (not including gasoline)}$$

In the 1937 Oregon study, the mileage costs of light trucks and heavy trucks were found to be 39 per cent and 59 per cent of the cost of operating tractor trailers. Applying these same percentages to the cost of 7.4 cents a mile of the tractor-trailer:

Vehicle Type	*Mileage Cost Cents Per Vehicle Mile (not including gasoline)*
Light truck	2.9
Heavy truck	4.4
Tractor-trailer	7.4

Unfortunately no literature available analyzes time costs of light and heavy trucks. It will be assumed, therefore, that the fixed time cost is proportional to the average empty truck weights as observed by the New York State Highway Planning Survey in 1947. (See Appendix III)

Vehicle Type	*Average Empty Weight*	*Fixed Time Costs (not including driver's wages)*
Light truck	4,330 lbs.	$0.73 per hour
Heavy truck	10,100	1.61
Tractor-trailer	19,000	3.13

Hourly wage rates as reported by an Albany trucking firm.

Vehicle Type	*Operator's Hourly Rate*
Light truck	$1.16 per hour
Heavy truck	1.63
Tractor-trailer	2.30

Increased Gasoline Consumption Due to Congestion

Every motorist is well aware that he gets a lower mileage per gallon in city driving than he does on the open road. A study by the Automobile Club of Southern California in 1942 measured this difference in consumption. A 1939 Dodge passenger car was equipped

with an Akroflex meter capable of measurements to the nearest twentieth of a gallon. The car made 22.3 miles a gallon on the open highway but only 8.7 miles a gallon on streets in heavily congested business areas. The best urban mileage reported was on Wilshire Boulevard where coordinated signals enabled operation at 18.4 miles a gallon. On other streets with traffic signals and stops necessitated at non-signalized intersections, the average performance was reduced to 14.9 miles a gallon.

No similar tests have been made on trucks, but it is reasonable to assume that gasoline consumption will vary in the same manner as passenger cars. The California Board of Equalization has determined the gasoline mileage on the open highway of the different weights of trucks. (See Table IV in the appendix.)

Using the average New York State truck weights found by the Highway Planning Survey, the gasoline mileage for the different classes of trucks are found. As a final step, by simple proportion, the following two tables have been prepared:

	MILES PER GALLON			
TYPE OF TRAVEL	*Pass. Veh.*	*Light Truck*	*Heavy Truck*	*Tractor Trailer*
Expressway	22.3	12.3	7.5	4.5
Arterial Street with coordinated Traffic Signals	18.4	10.1	6.2	3.7
Ordinary City Street	14.9	8.2	5.0	3.0
Heavily congested business area street	8.7	4.8	2.9	1.8

Cost per mile, using the above consumption data and a gasoline cost of twenty-three cents a gallon.

	GASOLINE COSTS—CENTS PER MILE			
TYPE OF TRAVEL	*Pass. Veh.*	*Light Truck*	*Heavy Truck*	*Tractor Trailer*
Expressway	1.1	1.9	3.1	5.1
Arterial Street with coordinated Traffic Signals	1.3	2.4	3.7	6.2
Ordinary City Street	1.5	2.8	4.6	7.7
Heavily congested business area street	2.6	4.8	7.9	12.8

Monetary Evaluation of Traffic Accidents

Perhaps the best way to realize the effect of highway design on the traffic accident picture is to list statistics on the causes of urban accidents. In cities and towns, three out of every five motor vehicle fatalities involve pedestrians. Intersection accidents are nearly 60 per cent of the total in urban areas. Finally the accident exposure rate is higher at night than in daylight.

Because there are no pedestrians or intersections at grades, expressways should have lower rates than urban streets. In addition opposing traffic is separated, the lighting at night is better, and a free flow condition results from improved traffic design. The accompanying table of fatality rates per hundred million vehicle-miles on parallel facilities proves that accident rates on limited access highways are lower.

In view of the values listed in the table the following fatality rates per hundred million vehicle-miles will be used:

1. Unimproved urban highways 15.0
2. Semi expressway (limited access, grade separations at major intersections) 6.3
3. Expressway (mixed traffic) 3.7
4. Parkway 3.0

COMPARISON OF ACCIDENT RATES ON DIFFERENT TYPE HIGHWAYS
(Deaths per hundred million vehicle miles)

Unimproved Urban Highway	*Semi-Expressway*	*Expressway (mixed traffic)*	*Parkway*
State Highway System on L.I., N.Y. 15	Sunrise Highway Ext. L. I., N.Y. 6		Parkway System on L. I., N.Y. 3.0
Boston Post Road Conn. 11.2			Merritt Parkway Conn. 3.5
Wilshire Blvd. Los Angeles, Cal. 21.0			Arroyo Seco Parkway Los Angeles, Cal. 3.0

Unimproved Urban Highway	*Semi-Expressway*	*Expressway (mixed traffic)*	*Parkway*
		Detroit Industrial & Division Exp. Detroit, Mich. 3.7	
State Highway System New Jersey 15.0	State Highway System New Jersey 6.6		Route 4 New Jersey 1.9

In this report each death will be assumed to represent a monetary value which will include all types of accidents. The National Safety Council calculated the total economic loss of motor vehicle accidents in 1946 as $2,200,060,000. In that same year there was a total of 33,770 automotive fatalities. Dividing $2,200,000,000 by 33,700 gives $65,000 lost on the average, per highway death.

The accident cost per mile will now be found for an urban through street.

15 deaths per hundred million vehicle miles

$$\text{cost} = \frac{15 \times 65{,}000}{100{,}000{,}000} \times \frac{1}{100}$$

$$= 0.98 \text{ cents per vehicle mile}$$

In a similar manner the accident costs can be found for the different types of highways.

Highway Type	*Accident Costs Cents per Vehicle-Mile*
Unimproved urban highway	0.98
Semi-expressway	0.41
Expressway	0.24
Parkway	0.20

Calculation of Economic Savings

The following table contains the time and mileage costs developed in the previous sections of this report:

TIME AND MILEAGE COSTS

	Pass. Cars	*Light Trucks*	*Heavy Trucks*	*Tractor Trailers*
Mileage cost, cents per mile (not including gasoline)	2.0	2.9	4.4	7.4
Vehicle & time cost dollars per hour	—	0.73	1.61	3.13
Operator's time valuation dollars per hour	1.10	1.16	1.63	2.30

GASOLINE COSTS, Cents per Mile

	Pass. Cars	*Light Trucks*	*Heavy Trucks*	*Tractor Trailers*
Congested Business Streets	2.6	4.8	7.9	12.8
Through City Street	1.5	2.8	4.6	7.7
Arterial Street with Coordinated Signals	1.3	2.4	3.7	6.2
Expressway	1.1	1.9	3.1	5.1

ACCIDENT COSTS, Cents per Vehicle-mile

1. Unimproved urban highway	0.98
2. Semi-expressway	0.41
3. Expressway	0.24
4. Parkway	0.20

The above table will now be consolidated by adding separately the time and mileage costs.

TOTAL MILEAGE COSTS, Cents per Mile

	Pass. Cars	*Light Trucks*	*Heavy Trucks*	*Tractor Trailers*
Congested Business Streets	5.6	8.7	13.3	21.2
Through City Street	4.5	6.7	10.0	16.1
Semi-Expressway	3.7	5.7	8.5	14.0
Expressway	3.3	5.0	7.7	12.7

TIME COSTS, Dollars per Hour

$1.10	$1.89	$3.24	$5.43

From a traffic count made at 20 loadometer stations by the New York State Highway Planning Survey, a mileage and time cost will now be found for a composite vehicle. The survey disclosed that 73.6 percent of the 22,904 vehicles were passenger cars, light trucks 14.1 percent, heavy trucks 6.1 percent, and tractor trailers 6.2 percent of the total.

COMPOSITE VEHICLE

MILEAGE COST, Cents per Mile

Congested Business Streets	7.4
Through City Street	5.9
Semi-Expressway	4.9
Expressway	4.4

TIME COST, Dollars per Hour $1.62

A quick estimate of the savings to motor vehicles can be obtained by first assigning average speed values to the four classes of highways. The average speed on a congested business street may be taken at ten miles an hour, on a through city street twenty miles an hour, thirty miles an hour on a semi-expressway with coordinated traffic signals, and on an expressway forty miles an hour. The time cost an hour, divided by the speed in miles an hour, gives the time cost in cents per mile.

COMPOSITE VEHICLE

TIME AND MILEAGE COSTS, Cents per Mile

Congested Business Streets	23.6
Through City Street	14.0
Semi-Expressway	10.3
Expressway	8.4

As an example, the economic benefits to be gained by building the Clinton Avenue Expressway in Rochester (N.Y.) will now be found.

	EXISTING ROUTE, 1963	PROPOSED ROUTE, 1963
Length	2.50 miles	2.50 miles
Traffic, Peak hour	6,000	6,000
Traffic, 24 hour	6,000 x 11.7 = 70,000	70,000
Time, min.	12.0 min.	3.8
Type	Congested Business St.	Expressway
Mileage Cost per Vehicle	2.5 x 7.5 = 18.8 cents	2.5 x 4.4 = 11.0¢
Time cost	$1.62 \times \frac{12.0}{60} = \frac{32.4 \text{ cents}}{51.2}$	$\$1.62 \times \frac{3.8}{60} = \frac{10.3}{21.3}$

Savings per vehicle	51.2 − 21.3 = 29.9 cents
Savings, 24 hours	$0.299 x 70,000 = $20,900
Savings, one year	20,900 x 365 = $7,630,000
Savings, 20 Years	7,630,000 x 20 = $153,000,000

Note: estimated 1940 cost of route is $4,884,800

Conclusion

The following table presents the results of this study. Using the values shown the total economic cost of operating vehicles over any highway can be found. In this manner the economic savings resulting from the construction of a new route can be found.

TOTAL MILEAGE COSTS, Cents per Mile

	Pass. Cars	*Light Trucks*	*Heavy Trucks*	*Tractor Trailers*
Congested Business Streets	5.6	8.7	13.3	21.2
Through City Street	4.5	6.7	10.0	16.1
Semi-Expressway	3.7	5.7	8.5	14.0
Expressway	3.3	5.0	7.7	12.7

TIME COSTS, Dollars per Hour

$1.10	$1.89	$3.24	$5.43

The same procedure should prove to be a valuable aid in selecting the type of interchange to be used at a given location. Knowing the traffic volumes, including turning movements, expected in 1965, a

design engineer could balance the economic value of vehicle operation and the construction cost for each suggested design of interchange. Along the same lines this method would also indicate any economic advantage of a grade separation versus an intersection at grade on an arterial route.

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Table I

AUTOMOBILE OPERATING COSTS—1938, OREGON
(The Economics of Highway Planning, 1938)

	Light	*Medium*	*Heavy*	*Composite*
Mileage Element Costs		*Cents per mile*		
Gas, 20 cents per gallon	1.25	1.54	1.67	1.32
Oil, 25 cents per quart	0.19	0.16	0.22	0.19
Tires and tubes	0.21	0.31	0.40	0.23
Maintenance	0.53	0.60	0.65	0.56
Depreciation (two-thirds) based on 7,000 miles	0.67	1.50	2.14	0.91
Total	2.85	4.11	5.08	3.21
Non-Mileage Element Costs				
Depreciation (one-third)	23.41	52.50	75.00	32.20
License	5.00	5.00	5.00	5.00
Garage (storage only)	36.00	36.00	36.00	36.00
Interest	18.72	42.00	60.00	25.50
Insurance	7.20	8.00	25.00	10.00
Total	90.33	143.50	201.00	108.70
Basic Data				
List Weight, Pounds	2600	3200	3900	2800
Cost new	625	1400	2000	840

Table II

AUTOMOBILE OPERATING COSTS—1931

(Iowa State College Bulletin No. 106, "Automobile Operating Cost and Mileage Study" by Robley Winfrey.)

Item	*Annual Cost*	*Cost Per Mile Cents*
Gasoline, 20 cents per gallon	88.90	1.27
Oil, 25 cents per quart	17.50	0.25
Tires and Tubes	30.10	0.43
Maintenance	85.40	1.22
Depreciation	114.10	1.63
License, Iowa rate	15.63	0.22
Garage, $4 per month	48.00	0.69
Interest, 6 per cent	35.12	0.47
Insurance, Ames rate	22.70	0.33
	455.45	6.51

NOTE: Annual mileage is 7000 miles

Table III

AVERAGE TRUCK WEIGHTS, 1947, NEW YORK STATE
(N. Y. S. Highway Planning Survey, field studies made at 20 lodometer stations, September, 1947)

Vehicle Type	*Distribution By Type (%)*	*Average Loaded Weight*	*Average Empty Weight*	*Average All Trucks Weighed*
SINGLE UNIT TRUCKS				
Pick-ups, light panels, etc.	27.24	4,773	3,972	4,394
Other single tired, 2 axle	6.14	7,387	5,988	6,728
Dual tired—2 axle	40.49	13,925	8,814	12,131
3 axle	2.82	27,894	12,706	19,838
Sub-total single unit trucks	76.69	12,144	7,409	10,273
TRACTOR TRUCKS, SEMI-TRAILERS				
3 axle	21.36	38,256	19,374	32,563
4 axle	1.75	51,418	24,713	47,349
5 axle	0.03	—	39,120	39,120
Sub-total tractor trucks & semi-trailers	23.14	39,839	19,726	34,065
TRUCKS & FULL TRAILERS				
4 axle & 5 axle	0.17	23,180	—	23,180
TOTAL—ALL TYPES	100.00	18,599	9,032	14,911

Table III—*Cont'd*

WEIGHTED AVERAGE OF THE THREE BASIC TRUCK TYPES

Vehicle Type	*Distribution By Type (%)*	*Average Loaded Weight*	*Average Empty Weight*	*Average All Trucks Weighed*
(2 axle trucks—single tired) Light Trucks	33.4	5,250	4,330	4,820
(Dual tired—2 & 3 axle) Heavy Trucks	43.3	16,200	10,100	13,800
Tractor—Trailers	23.1	39,800	19,700	34,000

Table IV

GASOLINE CONSUMPTION DATA FOR TRUCKS, 1938
(Board of Equalization, California)

Classification By Empty Weight Groups (lbs.)	*Miles Per Hour*	*Gallons Per Mile*
3,000– 4,000	14.67	.068
4,000– 5,000	12.75	.078
5,000– 6,000	10.78	.093
6,000– 7,000	9.70	.103
7,000– 8,000	8.83	.113
8,000– 9,000	7.97	.125
9,000–10,000	7.67	.130
10,000–11,000	7.48	.134
11,000–12,000	6.48	.154
12,000–13,000	6.08	.164
13,000–14,000	5.39	.186
14,000–15,000	5.11	.196
15,000–16,000	4.92	.203
16,000–17,000	4.80	.208
17,000–18,000	4.70	.213
18,000–19,000	4.60	.217
19,000 and over	4.50	.222

Table V

AVERAGE COST OF NEW CAR, 1947

Make	*1 New Cars Reg. NY State, 1st 6 Months, 1947*	*2 Detroit, Retail Price of Stripped Model*	*(1) × (2) = (3)*
			($ 000,000)
Buick	10,763	1822	19.5
Cadillac	3,307	2386	7.8
Chevrolet	18,461	1280	23.6
Chrysler	3,386	1990	6.7
Desoto	3,830	1590	6.1
Dodge	10,224	1450	14.7
Ford	14,132	1286	18.2
Frazer	1,320	2215	13.2
Hudson	3,502	1710	5.9
Kaiser	1,913	1994	3.8
Lincoln	1,088	2545	2.7
Mercury	3,312	1562	5.2

Make	*1 New Cars Reg. NY State, 1st 6 Months, 1947*	*2 Detroit, Retail Price of Stripped Model*	*(1) x (2) = (3)*
Nash	4,937	1500	7.4
Oldsmobile	8,169	1625	13.3
Packard	2,852	1947	5.6
Plymouth	11,254	1280	14.5
Pontiac	8,632	1480	12.8
Studebaker	7,824	1500	11.7
Willys	1,190	1250	1.5
Totals	120,096		194.2

Average Detroit Stripped Price.

$$= \frac{\text{N.Y.S. Total Price}}{\text{N.Y.S. New Registrations}}$$

$$= \frac{\$194{,}000{,}000}{120{,}096} = \$1680$$

The following data were obtained from the Albany, New York, Hudson Dealer (1947 Detroit Retail Stripped Price, $1710)

Detroit Stripped Price, 1948	$ 1988
Delivery & Federal Excise Tax	119
Freight	75
Dealer Handling	20
Albany Stripped Price	$ 2202
Average cost of factory installed accessories and retail accessories	$ 400
Average Albany Retail Price	$ 2600

Difference between Detroit Stripped Price and Albany Retail Price, 1948

Albany Retail	$ 2600
Detroit Stripped	−1988
	$ 612

1946 Addition to Detroit Stripped Price

$$= \frac{\text{1946 Stripped Price}}{\text{1948 Stripped Price}} \times \text{1948 Difference}$$

$$= \frac{1710}{1988} \times 612 = \$515$$

Weighted Average Price of Albany Passenger Car

Detroit Stripped Price	$1680
Addition to Stripped Price	515
	$2195

1 *Automotive Industries*, 30th Annual Statistical Issue, March 1948.
2 *Business Week*, Auto Industry Compares Prices, May 1947.

Cost Ratios of Passenger Cars & Trucks

The cost of motor vehicle transportation has been determined in "The Economic Evaluation of Urban Highway Improvements." The following table contains the results of this study.

TOTAL MILEAGE COSTS, Cents per Mile

	Pass. Cars	*Light Trucks*	*Heavy Trucks*	*Tractor Trailers*
Congested Business Streets	5.6	8.7	13.3	21.2
Through City Street	4.5	6.7	10.0	16.1
Semi-Expressway	3.7	5.7	8.5	14.0
Expressway	3.3	5.0	7.7	12.7
Time Costs, Dollars per hour	1.10	1.89	3.24	5.43

It is seen that operating costs will vary with the type of street facility used. A through city street may be taken as representative of urban conditions. This example would also apply to the urbanized sections of such highways as N.Y. 9 and the Boston Post Road.

The operating costs ratios can be calculated for this type of thoroughfare as follows. In order to convert time costs into mileage costs an average speed (including standing time) of 20 miles per

hour will be assumed. From these costs, by simple proportion, the operating ratios are found.

Cost Per Mile, Cents (Including Time Costs) Through City Streets
Total Time & Mileage Costs, Cents Per Mile

Pass. Cars	$4.5 + 1/20 \times 110 = 10.0$
Light Trucks	$6.7 + 1/20 \times 189 = 16.2$
Heavy Trucks	$10.0 + 1/20 \times 324 = 26.2$
Tractor Trailers	$16.1 + 1/20 \times 543 = 43.3$

The cost ratios for automobiles, light trucks, heavy trucks, and tractor-trailers are respectively 1.0, 1.6, 2.6, and 4.3. It may happen that trucks are merely classified as either light or heavy. In this instance the light and heavy trucks of the study will be averaged to get a light truck figure. The tractor-trailer figure will be used for the heavy truck. Rounding off the numbers to the nearest integer, the following cost ratios are determined.

Passenger Car	1
Light Truck	2
Heavy Truck	4

WATERTOWN

Economic Evaluation of the Plan

A recent study conducted by the Department of Public Works determined time and mileage costs of motor vehicle transportation. The time cost of a composite motor vehicle (including trucks) is 2.7 cents per minute. The mileage cost varies with traffic conditions; 7.4 cents a mile in a congested business area, 5.9 cents a mile on a through city street, 5.5 cents a mile on a street with progressive traffic signals, and 4.9 cents per mile on a semi-expressway such as the proposed loop highway.

The arterial streets in the city were divided into four major groups for purposes of analysis and the costs of vehicle operation computed on both the existing streets and the proposed arterial network. Computations were based on estimated 1963 traffic volumes.

These volumes are considered as mean values for the twenty year period of savings which will result from the development of the plan.

Street Groupings

North: Bradely, Leray, Mill and Pearl Streets
East : State, Gifford, Water and East Main Streets
South: Washington Street, U.S. 11
West : Arsenal, Coffeen and West Main Streets

In the accompanying table the costs of vehicle operation on both existing and proposed routes were divided into two parts. The first was that portion of the trip within the city and outside the proposed Loop. The second compares time and mileage costs between points on the proposed loop by travel (1) through the center of the city and (2) along the loop. The sum of these costs applied to the average traffic volumes along the radial routes gives the total vehicle operating costs.

Summarized from the following table.

Existing routes, 1963, 12 Hr.	$10,030
Proposed routes, 1963, 12 Hr.	– $ 6,090
Savings for 12 Hr. period	$ 3,940

The twelve hour traffic volume is normally two-thirds of the 24 hour count. Therefore:

21 Hr. savings x 1.5 = daily savings or:	
$3,940 x 1.5 = $5,900;	
Annual saving equals	$ 2,150,000
20 year saving equals	$43,000,000

Clearly the original investment would be repaid many times over by the economic savings to the community.

City Line to Loop to City Line

1963

	From	To	(1) Length	(2) Time (min.)	(3) 12-Hr. Count	1+3=4 Mileage Costs @ 5.9	2+3=5 Time Costs @ 2.7¢ min.	4+5=6 Total Costs
EXISTING	N	E	2.4	9.3	1800	$250	$450	700
		S	2.5	8.0	1800	270	390	660
		W	2.4	7.4	1800	250	360	610
	E	S	3.1	11.3	1200	220	370	590
		W	3.0	10.7	1200	210	350	560
		N	2.4	9.3	2300	410	580	910
	S	W	3.1	9.4	1000	180	250	430
		N	2.5	8.0	1000	140	220	360
		E	3.1	11.3	1000	180	300	480
	W	N	2.4	7.4	1200	170	240	410
		E	3.0	10.7	1200	210	350	560
		S	3.1	9.4	1200	220	300	520
						2710	4160	6870

City Line to Loop to City Line

	From	To	Length (min.)	Time (min.)	12-Hr. Count	Mileage Costs @ 5.5	Time Costs @ 2.7¢ min.	Total Costs
PROPOSED	N	E	2.4	4.8	1800	230	230	460
		S	2.5	5.0	1800	250	240	490
		W	2.4	4.8	1800	230	230	460
	E	S	3.1	6.2	1200	210	200	410
		W	3.0	6.0	1200	200	190	390
		N	2.4	4.8	2300	380	300	680
	S	W	3.1	6.2	1000	170	170	340
		N	2.5	5.0	1000	130	140	270
		E	3.1	6.2	1000	170	170	340
	W	N	2.4	4.8	1200	160	160	320
		E	3.0	6.0	1200	200	190	390
		S	3.1	6.2	1200	210	200	410
						2540	2420	4960

Loop to Public Square to Loop

1963

(1) Length	(2) Time	(3) 12-Hr. Count	Mileage Costs @ 7.4	Time Costs @ 2.7¢ min.	(7) Total Costs	6+7=8 Costs Radial+ Business District
1.1	5.5	1800	$140	$270	410	1110
0.9	5.2	1800	120	250	370	1013
1.0	5.2	1800	130	250	380	990
0.6	3.9	1200	50	130	180	770
0.7	3.9	1200	60	130	190	750
1.1	5.5	2300	190	330	520	1430
0.5	3.6	1000	40	100	140	570
0.9	5.2	1000	70	140	210	570
0.6	3.9	1000	40	110	150	630
1.0	5.2	1200	90	170	260	670
0.7	3.9	1200	60	130	190	750
0.5	3.6	1200	40	120	160	680
			1030	2130	3160	$10,030

Intersection on Loop to Intersection on Loop

Length	Time	12-Hr. Count	Mileage Costs @ 4.9	Time Costs @ 2.7¢ min.	Total Costs	Costs Radial+ Business District
0.6	1.2	1800	50	60	110	570
1.0	2.0	1800	90	100	190	680
0.6	1.2	1800	50	60	110	570
0.4	0.8	1200	20	30	50	460
0.9	1.8	1200	50	60	110	500
0.6	1.2	2300	70	40	110	790
0.5	1.0	1000	20	30	50	390
1.1	2.2	1000	50	60	110	380
0.4	0.8	1000	20	20	40	380
0.6	1.2	1200	40	40	80	400
0.9	1.8	1200	50	60	110	600
0.5	1.0	1200	30	30	60	470
			5.0	590	1130	6090